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FINAL

FEASIBILITY STUDY REPORT
OPERABLE UNIT NO. 6 (SITE 86)

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0303

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APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
ASTs	above ground storage tanks
Baker	Baker Environmental, Incorporated
bgs	below ground surface
BRA	baseline human health risk assessment
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
COCs	contaminants of concern
COPCs	contaminants of potential concern
CSFs	cancer slope factors
CWA	Clean Water Act
1,1-DCA	1,1-dichloroethane
1,2-DCE	1,2-dichloroethene
DEHNR	Department of Environmental Health and Natural Resources
DoN	Department of the Navy
DOT	Department of Transportation
FFA	Federal Facilities Agreement
FS	Feasibility Study
gpm	Gallons per Minute
HI	hazard index
ICR	estimated incremental lifetime cancer risk
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
NCAC	North Carolina Administrative Code
NC DENR	North Carolina Department of Environment and Natural Resources
NCGS	North Carolina General Statute
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCWQS	North Carolina Water Quality Standard

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NPW	Net Present Worth
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
O&M	Operation and Maintenance
ORP	oxidation-reduction potential
ppb	parts per billion
ppm	parts per million
PAH	polynuclear aromatic hydrocarbon
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
POTWs	publicly owned treatment works
PRAP	Proposed Remedial Action Plan
QI	quotient index
RAAs	remedial action alternatives
RCRA	Resource Conservation and Recovery Act
RfDs	reference doses
RI/FS	Remedial Investigation/Feasibility Study
RLs	remediation levels
RME	reasonable maximum exposure
ROD	Record of Decision
SA	site assessment
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SSSVs	surface soil screening values
STP	Sewage Treatment Plant
SVOCs	semivolatile organic compounds
TAL	target analyte list
TBC	to be considered
1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethene
TCL	target compound list
TDS	total dissolved solids
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRC	Technical Review Committee
TRVs	terrestrial reference values
TSS	total suspended solids

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

USEPA	United States Environmental Protection Agency
USGS	United States Geological Service
UST	underground storage tank
VOCs	volatile organic compounds

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the Feasibility Study (FS) conducted for Site 86 (the Tank Area AS419-AS421), one of five sites that comprise Operable Unit (OU) No. 6 at Marine Corps Air Station (MCAS), New River, North Carolina. Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0303 under the Department of the Navy (DoN) Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS is primarily based on data collected during a Remedial Investigation (RI) and a post-RI field investigation conducted for Site 86.

SITE HISTORY

Site 86 served as a storage area for petroleum products from 1954 to 1988. In 1954, three 25,000-gallon above ground storage tanks (ASTs) were installed within an earthen berm. Additionally, a small pump house was constructed to transfer fuel oil to and from the ASTs. The three tanks were reportedly used for No. 6 fuel oil storage until 1979. From 1979 to 1988, the tanks were used for temporary storage of waste oil. The three tanks were emptied in 1988 and are believed to have been removed in 1992. Today, the former location of the tanks is grass-covered and only a very slight depression remains.

REMEDIAL ACTION OBJECTIVES

Remedial action objectives for Site 86 were developed to address volatile organic compounds (VOCs) detected in the shallow aquifer at concentrations exceeding remediation levels. These VOCs include 1,2-dichloroethene (1,2-DCE), benzene, trichloroethene (TCE), and tetrachloroethene (PCE) that were detected in excess of the Federal and/or State criteria. The maximum detected concentrations were 140, 8, 400, and 77 micrograms per liter (µg/L), respectively. The Federal Maximum Contaminant Levels (MCLs) are 70 (for each *cis* and *trans* isomer), 1, 5, and 5 µg/L, respectively. 1,2-DCE does not have an associated North Carolina State Water Quality Standard (NCWQS). However, the (NCWQSs) for benzene, TCE, and PCE are 1, 2.8, and 0.7 µg/L, respectively.

The maximum VOC concentrations were detected in wells situated in the central and southeastern portion of the study area. However, VOCs were also detected (at lower concentrations) in surrounding monitoring wells. The dispersion and concentrations of VOCs at Site 86 suggests that the source of contamination may have been located within or immediately adjacent to the study area, possibly the aboveground storage tank area. Thus, an area of concern containing elevated VOC concentrations was delineated at Site 86, and remedial action objectives were developed to address this area of concern. These remedial action objectives are:

- Prevent future potential exposure to contaminated groundwater.
- Protect uncontaminated groundwater for future potential beneficial use.

Inorganics in groundwater were also detected at concentrations exceeding their remediation levels (RLs). Antimony, iron, and lead were detected at maximum concentrations of 23.6, 68,300, and 28.3 µg/L, respectively; their RLs developed in the FS are 6,300, and 15 µg/L, respectively.

However, these inorganic constituents were not addressed by the remedial action objectives. This is because 1) iron naturally occurs at high levels in groundwater and soil throughout the Base, and 2) future residential development of Site 86 is highly unlikely so risks generated under the future exposure scenario are extremely conservative and unlikely.

REMEDIAL ACTION ALTERNATIVES

Based on the remedial action objectives developed for Site 86, five remedial action alternatives (RAAs) were developed and evaluated:

- RAA 1: No Action
- RAA 2: Institutional Controls
- RAA 3: Monitored Natural Attenuation
- RAA 4: Extraction and On-Site Treatment
- RAA 5: In Situ Volatilization (In-Well Aeration)

The following paragraphs briefly describe these alternatives.

RAA 1: No Action

Capital Cost:	$0
Annual Operation and Maintenance (O&M) Cost:	$0
Net Present Worth (NPW):	$0
Time to Implement:	None

Under the no action RAA, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater at Site 86. The no action alternative is required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) to provide a baseline for comparison with other RAAs that provide a greater level of response. Although this RAA does not involve active remediation, passive remediation of the groundwater may occur via processes associated with the natural attenuation of contaminants. However, since there will be no monitoring conducted under RAA 1, it will be unknown how or if the natural attenuation processes would reduce contaminants at Site 86. Overall protection of human health and the environment will be unknown.

RAA 2: Institutional Controls

Capital Cost:	$0
Annual O&M Cost:	$26,000
NPW (30 years):	$400,000
Time to Implement:	Institutional controls could be implemented within half of one year.

Under RAA 2, a groundwater monitoring program and aquifer use restrictions will be implemented as institutional controls. Under the program, groundwater samples will be collected semiannually at six existing intermediate wells (86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW, and 86-GW25IW), and three existing deep wells (86-GW15DW, 86-GW16DW, 86-GW19DW). Samples collected from these wells will be analyzed for Target Compound List (TCL) VOCs. Additional wells may be added to the program, if necessary.

In addition to groundwater monitoring, the Base Master Plan will be modified to include institutional controls for aquifer use restrictions to prohibit future use of the aquifer within 1,500 feet of the estimated plume at Site 86. Further, there will be annual certification that the Base Master Plan restrictions will remain unchanged. Deed recordation of a Notice of Inactive Hazardous Substances or Waste Sites (required by North Carolina General Statute [NCGS] 130A-310.8(a)), and modification of the RCRA Permit Modification imposing the site restriction will be required. If the property is transferred from the United States Marines, MCB, Camp Lejeune shall record the site restrictions in the form of restrictive covenants at the Onslow County register of deeds' office prior to the transfer.

RAA 3: Monitored Natural Attenuation

Capital Cost:	$83,000
Annual O&M Cost (Years 1-5):	$93,000
Annual O&M Cost (Years 6-30):	$57,000
NPW (30 years):	$960,000
Time to Implement:	Institutional controls could be implemented within half of one year.

RAA 3 relies upon natural attenuation processes to passively treat the groundwater contamination. RAA 3 also includes a groundwater monitoring program and aquifer use restrictions that will be implemented as institutional controls.

The main component of RAA 3 is the monitoring program. Under this program, samples will be collected semiannually at 15 monitoring wells (86-GW08IW, 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW23IW, 86-GW25IW, 86-GW28IW, 86-GW29IW, 86-GW30IW, 86-GW31IW, 86-GW32IW, 86-GW15DW, 86-GW19DW, 86-GW31ID, and well AS428-GW06. The samples will be analyzed for TCL VOCs and natural attenuation parameters. Additional wells may be added to the program, if necessary. The monitoring program will identify the natural attenuation processes that are occurring at the site, track contaminant migration over time, indicate any fluctuations in contaminant levels, and monitor the progress of natural attenuation over time. Monitoring will continue until groundwater standards for the orgnaic COCs are met. RAA 3 also incorporates the option of annually updating the contaminant fate and transport model. Similar to RAA 2, this alternative also includes the same modifications to the Base Master Plan and institutional controls for aquifer use restrictions to prohibit future use of the surficial aquifer within 1,500 feet of the estimated plume at Site 86.

RAA 4: Extraction and On-Site Treatment

Capital Cost:	$532,000
Annual O&M Cost:	$59,000
NPW (30 years):	$1,440,000
Time to Implement:	Approximately 1.5 to 2 years would be required to design and construct the extraction and treatment system.

RAA 4 is a conventional extraction and treatment alternative in which three extraction wells will be installed to collect groundwater from the surficial aquifer. The capture radius of each extraction well has been estimated to be 100 feet. The pumping rate of each extraction well has been estimated to be 5 gpm. The extraction wells will be positioned so that their combined zones of influence intercept the maximum concentrations within the contaminant plume. Each extraction well will be screened at approximately 40 to 60 feet below ground surface (bgs).

After being extracted, the groundwater will be transported by pipeline to an on-site treatment plant. At the treatment plant, the groundwater will undergo suspended solids and metals removal via neutralization, precipitation, flocculation, sedimentation, and filtration units, and VOC treatment via a low profile air stripper. In addition, carbon adsorption will provide secondary treatment of the VOC emissions from the air stripper and of the treated groundwater. After receiving treatment, groundwater will be discharged to the existing storm drain system, which is expected to have the capacity to accept the 15 gallons per minute (gpm) discharge.

In addition to groundwater extraction, treatment, and discharge, RAA 4 incorporates the same groundwater monitoring program and aquifer use restrictions that are included under RAA 2 (i.e., annual certifications, recordation of a Notice of Inactive Hazardous Substances and Waste Disposal Sites, etc.).

RAA 5: In Situ Volatilization (In-Well Aeration)

Capital Cost:	$865,000
Annual O&M Cost:	$52,000
NPW (30 years):	$1,660,000
Time to Implement:	Approximately 1 to 1.5 years would be required to design and construct the in-well aeration system.

Under RAA 5, five aerations wells, each with an estimated capture radius of 65 feet, will be installed at Site 86. The wells will have overlapping capture radii that will intercept the area which contains the maximum detected VOC concentrations. A central treatment facility will house the associated knockout tanks, vacuum pumps and carbon adsorption units. The knockout tanks will remove any liquids that may have traveled up the well (the amount of knockout liquid is anticipated to be minimal) and the carbon adsorption units will treat off-gases that were stripped within the well. A field pilot test is recommended prior to the design of the in-well aeration system.

In addition to the in-well aeration system, RAA 5 incorporates the same groundwater monitoring program and aquifer use restrictions included under RAAs 2 and 4.

1.0 INTRODUCTION

This Feasibility Study (FS) has been prepared by Baker Environmental, Inc. (Baker) for the Department of the Navy (DoN), Atlantic Division Naval Facilities Engineering Command (LANTDIV), Comprehensive Long-Term Environmental Action Navy (CLEAN) Program. Activities associated with this FS have been conducted in accordance with requirements delineated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300.430) for Operable Unit (OU) No. 6 at Marine Corps Base (MCB), Camp Lejeune, North Carolina. The NCP guidelines, which dictate the FS process, were promulgated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA). The United States Environmental Protection Agency (USEPA) document Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988) provided guidance during the preparation of this report.

MCB, Camp Lejeune was placed on the Superfund National Priorities List (NPL) on October 4, 1989 (86 Federal Register 41015, 1989). Subsequent to this listing, USEPA Region IV; the North Carolina Department of Environment and Natural Resources (NC DENR); and the DoN entered into a Federal Facilities Agreement (FFA). The continuing purpose of the FFA is to ensure that environmental impacts associated with past and present activities at MCB, Camp Lejeune are thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives are developed and implemented, as necessary, to protect public health, welfare, and the environment (FFA, 1989).

The Fiscal Year 1997 Site Management Plan for MCB, Camp Lejeune (Baker, 1995), the primary document referenced in the FFA, identifies 42 sites that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 42 sites have been grouped into 18 operable units to simplify RI/FS activities. An RI was conducted at OU No. 6, Sites 36, 43, 44, 54, and 86 during 1995. This report provides the FS conducted for Site 86, Tank Area AS419-AS421 at Marine Corps Air Station (MCAS). Additional reports have been prepared that address each of the other OU No. 6 sites. Figure 1-1 depicts the location of the five sites that comprise OU No. 6. [Note that all tables and figures are presented in the back of each section.]

1.1 Purpose and Organization of the Report

The subsections which follow describe the purpose and organization of this FS report.

1.1.1 Purpose of the Feasibility Study

The purpose of this FS for Site 86 is to identify remedial action alternatives (RAAs) that are protective of human health and the environment, and that cost-effectively attain appropriate Federal and State requirements. In general, the FS process under CERCLA serves to ensure that appropriate RAAs are developed and evaluated, such that pertinent information concerning the remedial action options can be presented and an appropriate remedy selected. The FS involves two major phases:

1. Development and screening of RAAs, and
2. Detailed analysis of RAAs.

The first phase includes the following activities:

- Developing remedial action objectives and remediation levels (RLs)
- Developing general response actions
- Identifying volumes or areas of affected media
- Identifying and screening potential technologies and process options
- Evaluating process options
- Assembling alternatives
- Defining alternatives
- Screening and evaluating alternatives.

Section 121(b)(1) of CERCLA requires that an assessment of possible solutions and alternative treatment technologies or resource recovery technologies that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant be conducted. In addition, according to CERCLA, treatment alternatives should be developed ranging from an alternative that, to the degree possible, would eliminate the need for long-term management of alternatives which involve treatment that would reduce toxicity, mobility, or volume as their principal element. A containment option involving little or no treatment and a no-action alternative should also be developed.

The second phase of the FS consists of: (1) evaluating the potential alternatives in detail with respect to nine evaluation criteria that address statutory requirements and preferences of CERCLA; and (2) performing a comparison analysis of the evaluated alternatives.

1.1.2 Report Organization

This FS Report is organized in five sections. The Introduction (Section 1.0) presents the purpose of the report, a brief discussion of the FS process, and pertinent site background information including a summary of the nature and extent of contamination at Site 86. Information from both human health and ecological risk assessments are also presented in Section 1.0. Section 2.0 contains the remedial action objectives and RLs that have been established for the site. Section 3.0 contains the identification of general response actions, and the identification and preliminary screening of the remedial action technologies and process options. Sections 4.0 and 5.0 contain the development, detailed analysis, and comparison of RAAs for Site 86. The detailed analysis is based on a set of nine criteria including short- and long-term effectiveness, implementability, cost, acceptance, compliance with applicable regulations, and overall protection of human health and the environment. References are provided within each of the five sections.

1.2 Background and Setting of Site 86

The following section provides both the location and setting of Site 86. A brief summary of site history and previous investigation findings are also provided within this section.

1.2.1 Site Location and Setting

Site 86 is located on the southwest corner of the Foster and Campbell Street intersection, within the operations area of MCAS New River. Site 86 is also referred to as Tank Area AS419-AS421 at MCAS. The site is comprised of a lawn area surrounded by buildings, asphalt roads, and parking lots. In the center of the site is the former location of three above ground storage tanks (ASTs).

Concrete pylons, upon which electric and steam overhead utilities are mounted, line the northern, western, and southern boundaries of the site. Campbell Street borders the site to the north and Foster Street lies adjacent to the east. Immediately to the south of the study area is Building AS-502, the MCAS fire station. The entrance road to the fire station borders the Site 86 study area to the west. Figure 1-2 presents a site map of the Tank Area AS419-AS421.

The ground surface at Site 86 gently slopes to the south, toward a drainage ditch and culvert. Storm water drains that are located along Campbell Street receive runoff from only the northernmost portion of the study area. Stormwater from Site 86 eventually discharges into the New River, which lies approximately three quarters of a mile to the east.

1.2.1.1 Geology

With respect to geology, a similar depositional sequence was encountered in test borings completed throughout Site 86. The sequence generally matches the stratigraphic sequence discussed in the United States Geological Survey (USGS) report prepared for MCB, Camp Lejeune (Cardinell, et al., 1993). The uppermost formation at Site 86 consists of an undifferentiated formation. The Belgrade Formation was not observed at Site 86. The River Bend Formation lies immediately below the undifferentiated formation. The following discussion of subsurface lithology includes Site 86 and the MCAS, New River.

Soils at Site 86 have been disturbed through construction activities; observations of the site lithology suggest that surface soils have been reworked. Non-native material, including rock, glass, concrete, and coal fragments, was observed among the shallow soil test borings, typically to a depth of 3 feet. Non-native material was also observed to a depth of 9.5 feet and 7 feet, respectively in borings 86-AST-SB05 and 86-AST-SB06.

The uppermost formation at Site 86, the undifferentiated formation, consists of unconsolidated sediments of Holocene and Pleistocene ages. The formation typically extends to a depth of between 25 to 35 feet below ground surface (bgs). A clay layer was encountered at the surface south of the site and on the western portion of the site. A fine to medium sand layer occurs at the surface east of the site. Both the sand and clay layers are typically 5 to 15 feet thick, and tend to be thickest under Site 86. Below the sand and clay layers, is a predominantly fine to coarse sand layer; a fine sand replaces the medium sand west of the site. This fine to coarse sand layer is typically 15 to 30 feet thick, and thickens south and southwest of the site. A silty fine sand lies immediately below the fine to medium sand layer. This silty fine sand layer is typically 5 to 10 feet thick.

The River Bend Formation, which constitutes the uppermost unit of the Castle Hayne aquifer at the site, consists of several units of Oligocene age. This formation lies 25 to 35 feet bgs at Site 86. The uppermost unit is a fossiliferous limestone 5 to 15 feet thick. The limestone consists of cemented and partially cemented shell fragments in a calcareous matrix of fine sand, silt, or clay. A silty fine sand layer lies below the second limestone; the silty fine sand layer is 35 to 45 feet thick.

1.2.1.2 Hydrogeology

There are several aquifers beneath Site 86 and MCAS, New River. The uppermost two aquifers were investigated in the RI; the surficial aquifer and the Castle Hayne aquifer. The surficial aquifer, which is unconfined (i.e., water table aquifer), occurs within the sediments of the undifferentiated formation, typically within 10 feet of the surface. The upper portion of the Castle Hayne aquifer occurs within the sediments of the River Bend Formation. According to Cardinell, the Castle Hayne aquifer is approximately 200 feet thick in the vicinity of Camp Geiger and the MCAS.

Groundwater flow in the surficial aquifer at Site 86 is north, with an average velocity of 0.005 feet per day. Groundwater flow in the lower portion of the surficial aquifer is generally to the northeast. Groundwater flow in the upper portion of the Castle Hayne aquifer is to the east-northeast, with an average velocity of 0.003 feet per day. Because hydraulic conductivity varies, groundwater may exhibit preferential flow paths following the relatively high conductive medium-grained sands. In addition, there appears to be some degree of connection between the surficial and Castle Hayne aquifers.

1.2.2 Site History

Site 86 served as a storage area for petroleum products from 1954 to 1988. In 1954, three 25,000-gallon ASTs were installed within an earthen berm. Additionally, a small pump house was constructed to transfer fuel oil to and from the ASTs. The three tanks were reportedly used for No.6 fuel oil storage until 1979. From 1979 to 1988, the tanks were used for temporary storage of waste oil (O'Brien & Gere, 1992). The three tanks were emptied in 1988 and are believed to have been removed in 1992. Today, the former location of the tanks is grass-covered and only a very slight depression remains.

1.2.3 Previous Investigations

The subsections which follow detail previous investigation activities and information regarding Site 86. Note that since Site 86 was only added to the list of MCB, Camp Lejeune Installation Restoration sites in 1992, the Initial Assessment Study and the Confirmational Study for MCB, Camp Lejeune did not include Site 86.

1.2.3.1 <u>Preliminary Site Investigation</u>

A preliminary site investigation was conducted in November 1990 by Dewberry and Davis, Inc. During this investigation, a total of eleven soil boring samples were collected and analyzed for total petroleum hydrocarbons (TPH) and volatile organic compounds (VOCs). The soil samples were retained from areas immediately adjacent to the ASTs and ancillary piping. Two of the soil samples contained positive TPH detections:

- 7000 milligrams per kilogram (mg/kg) TPH in a sample obtained from 1-2 feet bgs
- 200 mg/kg total TPH in a sample obtained from 0.5-2 feet bgs

TPH results from the other nine soil samples were below the detection limit of 10 mg/kg or parts per million (ppm). Soil analyses for VOCs yielded concentrations of chloroform, methylene chloride, 1,1,1-trichloroethane (1,1,1-TCA), and 1,1,2-trichlorotrifluoroethane. The maximum VOC concentration was that of 1,1,2-trichlorotrifluoroethane at 61 mg/kg. Based upon the dispersion and concentration of detected compounds in surface soils at Site 86, the preliminary site investigation concluded that observations were indicative of localized surface spills.

1.2.3.2 Site Assessment

In 1992, a site assessment (SA) was conducted at Site 86 by O'Brien and Gere Engineers, Inc. The SA sought to determine the nature and presence of subsurface contamination that may have resulted from the temporary storage of waste petroleum products in the three ASTs located on site. As part of the SA, both groundwater and soil investigations were conducted. In addition, estimates of hydraulic conductivity were also calculated for each of the monitoring wells installed during the SA.

A total of 11 soil borings were completed as part of the SA investigation at Site 86. Four of the 11 soil borings were situated within the former AST area. The remaining seven soil borings were converted to monitoring wells, one from each well nest. TPH results from 21 of the 22 soil samples submitted for TPH analysis were below the North Carolina action level of 10 mg/kg. The soil sample that exceeded the State TPH action level was obtained within the former tank area, from a depth of four to six feet bgs. The TPH concentration at this location was 124 mg/kg.

The following subsections briefly describe the results and conclusions of the SA at Site 86. The following eight organic compounds were detected in at least one of the groundwater samples:

- benzene
- toluene
- 1,1-dichloroethane (1,1-DCA)
- 1,2-dichloroethene (1,2-DCE)
- trichloroethene (TCE)
- tetrachloroethene (PCE)
- chloroethane
- 1,1,1-TCA

Benzene, TCE, and PCE were detected above their corresponding North Carolina Water Quality Standard (NCWQS) in one or more of the Site 86 groundwater samples. Toluene and 1,1,1-TCA were each detected below their corresponding NCWQS. The organic compounds 1,1-DCE, 1,2-DCE, and chloroethane were detected in at least one of the five monitoring wells with organic contamination; however, these compounds do not have established NCWQSs.

1.3 Remedial Investigations

A RI was conducted at Site 86 from February through May 1995 by Baker (Baker, 1996). The RI consisted of a soil investigation, a groundwater investigation, and a habitat evaluation. In June of 1997, a post-RI field investigation was conducted which focused on VOCs in groundwater (Baker, 1997). Both of these investigations are described below.

1.3.1 Remedial Investigation

The RI field investigations at Site 86 were initiated to assess the nature and extent of contamination that may have resulted from previous management practices or site activities; assess the human health, ecological, and environmental risks associated with exposure to site media; and characterize the geologic and hydrogeologic setting of the study area. This section discusses the site-specific RI field investigation activities that were conducted to fulfill that objective. The RI field investigation was conducted during 1995 and consisted of a site survey; a soil investigation, which involved direct-push sample collection; a groundwater investigation, which included temporary and shallow monitoring well installation, sampling, and aquifer testing; and a habitat evaluation.

The number of test borings completed, monitoring wells installed, and monitoring wells sampled during the RI is summarized below:

- Soil Test Borings Completed 20
- Existing Shallow Wells Sampled 7
- Existing Intermediate Wells Sampled 7
- Shallow Wells Installed and Sampled 2
- Intermediate Wells Installed and Sampled 9
- Deep Wells Installed and Sampled 5

The following provides an overview of the various investigation activities carried out during the RI.

1.3.1.1 Soil Investigation

The sampling distribution employed at Site 86 was intended to identify if contamination was present and, if so, to evaluate the vertical and horizontal extent within the study area. The soil sampling program focused on known or suspected areas which may have been impacted by site storage operations. Previous investigatory data and background reports were used to locate potential sampling locations.

A total of 20 borings were completed at Site 86 to assess the suspected impact of former operations; four of those borings were utilized for the installation of monitoring wells. Twelve of the 20 borings (SB01 through SB12) were collected from within and immediately adjacent to the former storage tank area, as stipulated in the Final RI/FS Work Plan for OU No. 6 (Baker, 1994). The remaining four soil borings (WA-SB01, WA-SB02, CP-SB01, and CP-SB02) were collected from two separate locations where ancillary piping and equipment associated with the former storage tanks were located. One additional boring, to the north of the study area, was advanced to assess background contaminant concentrations. Figure 1-2 depicts soil sampling locations at Site 86.

Representative soil samples from the Site 86 study area were submitted for laboratory analysis of target compound list (TCL) organics (i.e., VOCs, semivolatile organic compounds [SVOCs], pesticides, and polychlorinated biphenyls [PCBs]), TPH, and target analyte list (TAL) metals.

1.3.1.2 Groundwater Investigation

Groundwater sampling events were conducted in March, April, May, and October of 1995. During March of 1995, groundwater samples were collected and submitted for laboratory analysis from seven existing shallow (86-GW01, 86-GW03, 86-GW05, 86-GW07, 86-GW09, 86-GW11, and 86-GW13), seven existing intermediate monitoring wells (86-GW02IW, 86-GW04IW, 86-GW06IW, 86-GW08IW, 86-GW10IW, 86-GW12IW, and 86-GW14IW), three newly installed intermediate wells (86-GW15IW through 86-GW17IW), and five newly installed deep wells (86-GW15DW through 86-GW19DW). Based upon preliminary analytical results from these monitoring wells, an additional four intermediate monitoring wells were proposed to further define the horizontal extent of site contamination. One of the four additional intermediate monitoring wells was installed within 75 feet of the former ASTs (86-GW20IW); the remaining three intermediate monitoring wells were installed over 300 feet to the south and southeast of the study area (86-GW21IW, 86-GW22IW, and 86-GW23IW). Samples from the four additional intermediate wells were submitted for laboratory analysis during April and May of 1995.

Analytical results generated during the March, April, and May groundwater investigations at Site 86 indicated the presence of surficial groundwater contamination. An additional four monitoring wells, two shallow (86-GW25 and 86-GW27) and two intermediate (86-GW24IW and 86-GW26IW), were installed to determine if the observed contaminants were the result of on-site operations or the product of an upgradient source. The four additional monitoring wells were installed during October of 1995. The two well clusters were placed to the south and southwest of the study area, each cluster with one shallow and one intermediate well. Figure 1-2 depicts the 30 groundwater RI sampling locations at Site 86.

During the March, April, and/or May sampling events, samples from each of the 14 existing wells (86-GW01 through 86-GW14IW), 4 of the newly installed intermediate wells (86-GW15IW, 86-GW16IW, 86-GW17IW, and 86-GW20IW), and the 5 newly installed deep wells (86-GW15DW, 86-GW16DW, 86-GW17DW, 86-GW18DW, and 86-GW19DW) were analyzed for full TCL VOCs, TCL SVOCs, TAL total metals, total suspended solids (TSS), and total dissolved solids (TDS). Groundwater samples obtained from three intermediate wells (86-GW21IW, 86-GW22IW, and 86-GW23IW) to the south and southeast of the study area were analyzed for TCL VOCs, TAL metals, TSS, and TDS. In addition, a limited number of groundwater samples were also analyzed for TCL pesticides, TCL PCBs, and TAL dissolved metals.

During October of 1995 an additional groundwater sampling event was conducted at Site 86 to confirm the presence of volatile organic compounds in the surficial aquifer. During this sampling event, groundwater samples were collected from 11 of the monitoring wells that exhibited volatile contaminants during the initial sampling rounds. In addition, samples were collected from two newly installed shallow and two newly installed intermediate monitoring wells. Each of the 15 samples were submitted for laboratory analysis of TCL VOCs only.

1.3.2 Post-RI Field Investigation

Based on the RI information for Site 86, it was determined that additional analytical data would be needed in order to select the most appropriate remedial alternative for Site 86. As a result, a post-RI field investigation was conducted. The investigation included the installation and sampling of additional monitoring wells at Site 86 and the sampling of existing wells to collect site-specific data. The following provides an overview of the various investigation activities carried out during the post-RI field investigation:

• Existing Intermediate Wells Sampled	2
• Existing Underground Storage Tank (UST) Well Sampled	1
• Intermediate Wells Installed and Sampled	4

As part of the post-RI, three monitoring wells, 86-GW28IW, 86-GW29IW, and 86-GW30IW, were installed in June, 1997. The wells were sampled on July 1, 1997 and analyzed for TCL VOCs. The locations of the newly installed wells are provided in Figure 1-2. Monitoring well 86-GW28IW is located downgradient, in the direction of groundwater flow, while monitoring well 86-GW30IW is located to the southwest, upgradient of the initial volatile detections. Based on the results of samples collected from 86-GW29IW, a historical aerial photograph review was conducted, and a fourth well (86-GW31IW) was installed downgradient from 86-GW29IW and sampled. In addition, sampling of existing wells (86-GW16IW, the UST well AS428 GW06, and 86-GW29IW) was conducted in September 1997.

1.4 Nature and Extent of Potential Site Contaminants

A brief summary of site contamination identified at Site 86 is presented within the subsections which follow. The following summary focuses on the primary site concerns and is not intended to address all media or analytical results in detail. Detailed findings and an evaluation of analytical data are presented in the RI Report (Baker, 1996) or the Post-RI Field Investigation Letter Report (Baker, 1997). A summary of site contamination detected during the RI by media is provided in Table 1-1.

1.4.1 Soil

Soil samples were collected and analyzed only during the RI, not the post-RI. VOCs were detected in two surface and four subsurface soil samples obtained from Site 86. The positive detections were identified in samples from within and immediately adjacent to the former AST area. Total xylenes were detected in one surface and two subsurface samples, each at a concentration of 5 micrograms per kilogram (µg/kg). Toluene was detected once among both surface and subsurface soil samples at concentrations of 25 and 250 µg/kg. Carbon disulfide was detected in a single subsurface soil sample at a concentration of 3 µg/kg. The localized occurrence of VOCs among soil samples obtained at Site 86 suggests that their presence is most likely related to past storage and transferal, through ancillary piping, of waste fuel products from the former ASTs.

SVOCs were identified in both surface and subsurface soil samples obtained from Site 86. The highest positive SVOC detections were limited to samples obtained from the first foot of surface soils. The concentrations of SVOCs detected in soil samples obtained at Site 86 varied widely, ranging from 37 µg/kg of dibenzo(a,h)anthracene to 3,500 µg/kg of fluoranthene. The horizontal distribution and concentrations of SVOCs suggests that contaminants have migrated via surface water from surrounding paved areas. Recently, Site 86 has been used as a contractor staging area for heavy equipment, materials, and vehicles. Exhaust from vehicles and heavy equipment may account for the dispersion of SVOCs throughout Site 86. The presence and dispersion of SVOCs in soil, particularly polynuclear aromatic hydrocarbon (PAH) compounds, is most likely the result of surface water runoff from surrounding paved portions of MCAS, New River and vehicle exhaust.

Positive pesticide detections were observed in both surface and subsurface soil samples throughout Site 86. The detected pesticide levels were low and most likely the result of routine Base-wide pesticide application and use. The maximum concentration of any one pesticide detected among the soil samples obtained from Site 86 was that of dieldrin at 44 µg/kg. The frequency and overall concentrations of detected pesticides in soil does not suggest the occurrence of pesticide disposal activities at Site 86.

A number of samples submitted for analyses had TAL metal concentrations greater than twice their average Base-specific background concentration. Inorganic analytes were detected in both surface and subsurface soil samples throughout the study area. Chromium and lead were detected at concentrations exceeding twice their average Base-specific background levels in 17 of the 27 soil samples each. The maximum concentrations of metals in samples obtained from the study area were generally detected in samples obtained from within or immediately adjacent to the former AST area. Although observed concentrations of TAL metals at Site 86 are not indicative of disposal operations or process by-products, elevated detections of metals in samples obtained from the AST area suggests that their presence may correlate to detections of organic compounds.

1.4.2 Groundwater

Groundwater samples were collected and analyzed for both the RI and the post-RI field investigations. Samples collected during the post-RI field investigation were only analyzed for VOCs.

RI and post-RI positive detections of organic compounds in groundwater samples collected at Site 86 are depicted on Figure 1-3. Figure 1-4 presents TAL metal sampling results in excess of either a Federal Maximum Contaminant Level (MCL) or NCWQS. Positive detection summaries of organic compounds in groundwater sampled during the RI are presented in Table 1-2; summaries for inorganic analytes (RI) are provided in Table 1-3. Table 1-4 presents the positive detection summaries of the organics (VOCs) detected in the post-RI groundwater samples. Pesticide and PCB compounds were not detected in any of the groundwater samples submitted for analyses from Site 86. As a result of those analyses, the extent of pesticide and PCB contamination in groundwater will not be addressed.

1.4.2.1 <u>Remedial Investigation Results</u>

Positive detections of VOCs were limited to samples obtained from the shallow aquifer. The lack of positive VOC detections in samples obtained from the Castle Hayne aquifer suggests that these contaminants have not migrated vertically from the surficial aquifer. A total of five VOCs were detected among two shallow and ten intermediate monitoring wells at Site 86: benzene; 1,1-DCA; 1,2-DCE; TCE; and PCE. The majority of higher volatile detections were observed in samples obtained from intermediate monitoring wells in the central and southeastern portions of the study area; however, at least five monitoring wells located to the northeast and southwest exhibited low concentrations of similar compounds. The highest concentration of a single VOC, TCE at 400 μg/L, was detected in well 86-GW20IW. Monitoring well 86-GW20IW lies within the central portion of the study area (refer to Figure 1-3). Four of the five other volatile compounds were detected among the four intermediate wells in that vicinity.

A number of positive VOC detections exceeded applicable State or Federal screening standards in groundwater samples obtained from the surficial aquifer at Site 86. The maximum VOC concentrations were detected in intermediate wells 86-GW10IW, 86-GW15IW, and 86-GW20IW (Table 1-1). Monitoring wells 86-GW10IW and 86-GW20IW are situated in the central and southeastern portion of the study area; 86-GW15IW is located beyond the southeastern boundary of the study area. Each of the three monitoring wells with maximum VOC concentrations are situated within an area surrounded by additional shallow and intermediate monitoring wells. Although VOCs were detected in the surrounding monitoring wells, the concentrations of the observed contaminants were either lower or not detected at all. The dispersion and concentrations of VOCs at Site 86 suggests that a source of these contaminants may have been located within or immediately adjacent to the study area, possibly the former ASTs.

SVOCs were detected in only 3 of the 23 groundwater samples submitted for laboratory analyses from Site 86. No SVOCs were detected in the five samples obtained below the semi-confining layer which separates the surficial and Castle Hayne aquifers at Site 86.

A total of four SVOCs were detected among samples obtained from one shallow and two intermediate monitoring wells at Site 86: dibenzofuran, fluorene, di-n-butylphthalate, and napthalene (refer to Figure 1-3). Three of the four SVOCs were detected at concentrations of less than 10 µg/L. The maximum SVOC concentration was that of di-n-butylphthalate at 23 µg/L. None of the SVOC detections exceeded applicable water quality standards. Positive detections of SVOCs were limited to the northeastern and southeastern portions of the study area. Based upon laboratory analytical results from the groundwater investigation at Site 86, no apparent pattern of SVOC dispersal is evident.

Inorganic analytes were detected in each of the groundwater samples submitted for total metal analyses from Site 86. Iron and manganese were detected most frequently among the groundwater samples, at levels in excess of either a Federal MCL or NCWQS (refer to Figure 1-4). Positive detections of both iron and manganese were distributed throughout the site, indicative of natural site conditions rather than disposal activities. Antimony was detected within one sample obtained from a deep monitoring well (86-GW16DW) at a concentration of 23.6 µg/L which exceeded the NCWQS of 6 µg/L. Lead was detected in only one of the groundwater samples obtained from Site 86. The concentration of lead in the sample obtained from intermediate well 86-GW06IW was 28.3 µg/L, which exceeded the NCWQS of 15 µg/L. In general, higher concentrations of TAL total metals were detected in groundwater samples obtained from the surficial aquifer.

Iron and manganese concentrations from a number of wells at Site 86 exceeded the NCWQS but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. Additionally, positive detections of both iron and manganese among groundwater samples retained from the upper-most portion of the surficial aquifer had no discernible pattern of distribution. The presence and concentrations of both iron and manganese in groundwater samples obtained at Site 86 appear to be indicative of natural site conditions rather than disposal activities.

1.4.2.2 Post-RI Results

Results of the post-RI groundwater sampling indicated that two of the monitoring wells had analytical results that were below all of the TCL VOC detection limits (86-GW28IW and 86-GW30IW). The analytical results which confirmed the non-detection of volatiles in monitoring well 86-GW30IW support the conclusion that the groundwater VOC plume identified in the vicinity of the previous ASTs is not the result of the migration of an off-site, upgradient source. In addition, the volatile non-detection results of the sample collected from 86-GW28IW helps to define the downgradient limits of the estimated extent of the VOC plume.

The analytical results associated with the sample collected in July, 1997 from monitoring well 86-GW29IW indicated the presence of TCE at a concentration of 600 micrograms per liter (µg/L) and 1,2-DCE at a concentration of 56 µg/L. This TCE concentration was higher than the maximum TCE concentration detected during the RI from monitoring well 86-GW10IW. The location and maximum TCE concentration detected in 86-GW29IW, with respect to the close proximity and low level of TCE within RI monitoring well 86-GW16IW, prompted a series of investigations and data searches.

Historical aerial photographs dating back to the early 1950s were reviewed to gain insight into the development of the area surrounding Site 86. Site plans and equipment layouts were reviewed in order to gain knowledge as to the use and/or possible connection to the existing VOC plume. During this search, two unrelated pieces of information were collected. During the 1950s, a para loft, a generating station, and a battery shop were all identified structures located directly east of the ASTs previously located at Site 86. Although these buildings were identified, no information surfaced that would lead to a direct connection with the VOC plume. During a field visit of the adjoining properties and buildings, several UST monitoring wells were discovered to the east of the site. These UST monitoring wells are part of a separate investigation and were not sampled for chlorinated compounds. Similar to the findings of the document search, the field visit did not produce evidence that the adjoining properties or buildings were the source of the VOC detections at monitoring well 86-GW29IW.

Based on the VOC detections noted in monitoring well 86-GW29IW, it was agreed that the installation of a fourth monitoring well (86-GW31IW) and the collection of additional groundwater samples from monitoring well 86-GW16IW, the UST well AS428 GW06, and monitoring well 86-GW29IW would better define the plume. Therefore, samples were initially collected on September 7, 1997, from monitoring wells 86-GW16IW and AS428 GW06. TCE was detected within 86-GW16IW at a concentration of 2 J µg/L and 1,2-DCE was detected at a concentration of 3 J µg/L. These results were consistent with the RI results obtained from well 86-GW16IW. Positive detections of TCE (2 J µg/L), 1,2-DCE (50 µg/L), and benzene (3 J µg/L) were detected in the UST well AS428-GW06. These results were used to best place the fourth monitoring well (86-GW31IW) downgradient of 86-GW29IW. Following the installation of monitoring well 86-GW31IW, groundwater samples were collected on September 17, 1997 from this well and from monitoring well 86-GW29IW. TCL VOCs were detected in both of these wells as follows:

• 86-GW29IW:	TCE	700 D µg/L
	1,2-DCE	67 D µg/L
	Vinyl Chloride (VC)	2 J µg/L
• 86-GW31IW:	TCE	9 J µg/L
	1,2-DCE	2 J µg/L

Although the post-RI TCE groundwater results were higher than the detections noted during the RI, the results were not significantly higher (i.e., 400 vs. 700 D µg/L). In addition, the overall proximity of the maximum TCE detection to the site and its close proximity to significantly lower VOC detections (GW16IW, GW28IW, and GW31IW), it is evaluated that the results of the post-RI field investigation for Site 86 have sufficiently identified the limits of the VOC plume.

1.5 Human Health Risk Assessment

Conclusions from the baseline human health risk assessment (BRA) are presented in the subsections which follow. Current and future potential receptors were evaluated for possible exposure to site media, including current military personnel, current trespassers (i.e., children and adults), future residents (i.e., children and adults), and future construction workers. The total risk from the site to these receptors was estimated by logically summing the multiple pathways likely to affect the receptor during a given activity. Exposure to surface soil was assessed for current trespassers and military receptors. Construction workers were assessed for possible exposure to surface and subsurface soil. Subsurface soil and groundwater exposures were evaluated for future residents. (A conceptual site model is located in Appendix S of the Final RI Report for Site 86.) Tables 1-5 and 1-6 present a summary of the estimated current and future potential human health risks associated with exposure to site media.

1.5.1 Current Scenario

The following potential current receptors were assessed: military personnel and trespassers (adults and children). Receptor exposure to surface soil was evaluated. As a result of those evaluations, potential risks associated with potential receptors were found to be within acceptable risk levels (Table 1-5).

1.5.2 Future Scenario

Future potential child and adult residents were assessed for possible exposure to groundwater and subsurface soil. A construction worker was evaluated for exposure to subsurface soil. There were no unacceptable risks associated with the construction worker. However, there were potential noncarcinogenic risks calculated for the future child resident (19) from groundwater exposure (a description of noncarcinogenic and carcinogenic risk values is presented in detail in Section 2.3.3 of this FS). Similarly, there was a noncarcinogenic risk (8) and carcinogenic risk (1.3×10^{-4}) calculated for the future adult resident from groundwater exposure (Table 1-6). These risk values exceeded the acceptable risk values of 1.0 for noncarcinogenic and 1×10^{-4} for carcinogenic effects. The maximum level of iron in groundwater was a primary contributor to these risks. In addition, possible exposure to the maximum concentration of lead in groundwater indicated a potential for adverse health effects for a child receptor.

Groundwater at Site 86 is not used as a potable source and future residential development of the site is unlikely. Based on this information, future exposure to groundwater is unlikely to occur. Additionally, iron is an essential nutrient. The toxicity values associated with exposure to iron are based on provisional studies, which have not been verified by USEPA. In fact, if iron were removed from the evaluation of risk due to groundwater ingestion, the noncarcinogenic risk for the child would decrease from 18 to 3 and, for the adult, from 8 to 1.6, which are only slightly greater than the acceptable noncarcinogenic risk value of 1.0. The noncarcinogenic risk from exposure to subsurface soil for the child receptor (which is already below the acceptable risk value of 1.0) would also decrease if iron were removed from the evaluation. The potential human health risks associated with exposure to iron in groundwater and subsurface soil represent a conservative and unrealistic estimate.

1.6 <u>Ecological Risk Assessment</u>

Assessment criteria were used to evaluate the risks posed to terrestrial receptor populations or subpopulations by possible exposure to site media. Several organic compounds and inorganic analytes were detected at concentrations that exceeded applicable surface soil screening values (SSSVs). A comparison of chronic daily intake (CDI) versus terrestrial reference values (TRVs) was also performed for Site 86. Of all five terrestrial species evaluated, the CDI exceeded the TRV for only the cottontail rabbit. Potential exposure risks for the cottontail rabbit, quotient index (QI) of 2.2, slightly exceeded the QI reference of 1.0. Therefore, a low risk potential to terrestrial species is posed by exposure to site media.

Some potential impacts to soil invertebrates and plants may occur as a result of potential exposure to site media. There is also a slight potential for a decrease in the terrestrial vertebrate population from exposure to site media based on the terrestrial intake model. It should be noted, however, that SSSVs incorporate much uncertainty into the evaluation of ecological risks and that the habitat at

Site 86 (mowed field within an industrial setting) is not expected to support an ecologically diverse population.

1.7 Remedial Investigation Conclusions

Based upon the information and findings supplied within the RI report, the following conclusions for Site 86 are presented.

1.7.1 Carcinogenic Human Health Risks

Multiple exposure pathways were evaluated for current and future potential human receptors at Site 86; conservative estimates indicate that carcinogenic site risks are within the acceptable risk range as defined by USEPA for all current potential receptors. There was, however, a potential future carcinogenic risk posed by ingestion of groundwater. Possible future adult residents could, under assumed conditions, be adversely affected by ingestion of iron at the maximum concentration detected among all groundwater samples. There were no unacceptable carcinogenic risks to future child residents.

1.7.2 Noncarcinogenic Human Health Risks

An assessment of potential noncarcinogenic risks posed by exposure to environmental media at Site 86 was also completed for possible current and future human receptors. This conservative evaluation of site risk suggests that future residents, given a number of exposure assumptions, could experience some adverse health effects. The evaluation was based upon the potential exposure of future child and future adult residents. A majority of the noncarcinogenic risks generated by the future residential scenario was the result of presumed shallow groundwater and subsurface soil ingestion. Ingestion of iron at the maximum concentrations detected among groundwater samples obtained from Site 86 was used in the estimation of risk. Additionally, ingestion of iron and lead at the maximum concentrations detected among soil samples constituted much of the remaining noncarcinogenic risk to future child residents. It is important to note that this risk assessment is highly protective of human health, and that future residential development of the site is unlikely.

1.7.3 Surficial Aquifer as Drinking Water Source

The majority of site-related carcinogenic and noncarcinogenic risk to future residents was generated by possible ingestion of inorganic analytes in groundwater. Hydraulic conductivity results from Site 86 suggest that potable wells supplying groundwater for human consumption from the surficial aquifer would not be practical. Groundwater flow rates would not be sufficient to support a potable source of drinking water. In addition, suspended material resulting from loose surficial soils would further inhibit groundwater flow capacities through siltation. Given these circumstances, it is unlikely that the surficial aquifer could be used as a drinking water source. If a potable well were required in the future at Site 86, it would most likely supply groundwater from the deeper Castle Hayne aquifer.

1.7.4 Ecological Risks

An ecological risk assessment of potential site-related impacts to terrestrial ecosystems was performed. Based upon this assessment, the significance of potential risks to ecological receptors at Site 86 is considered slight. Environmental media were assessed to determine the theoretical risks posed to various on-site ecological communities. The assessment also suggests that a majority of site-related risks posed to the terrestrial environment are a result of naturally occurring inorganic analytes detected in site media. Similar terrestrial risks have been demonstrated by reference samples collected throughout MCB, Camp Lejeune from areas not known or suspected of having been impacted by facility operations.

1.7.5 Positive Detections in Excess of Screening Criteria

A number of organic compounds and inorganic analytes were detected among groundwater samples collected during the RI that were obtained from Site 86 at concentrations which exceeded screening criteria promulgated by either State or Federal agencies. Positive detections of organic compounds in groundwater were limited to the central and southern portions of the study area. Twelve positive detections of TCE and four detections of PCE exceeded their respective NCWQS of 2.8 and 0.7 μg/L. The VOC, 1,2-DCE, was detected above the Federal MCL (70 μg/L) at two locations. Benzene was detected seven times among groundwater samples; each of the seven positive detections exceeded the NCWQS of 1 μg/L. The maximum TCE, benzene, and PCE detections were 400, 8, and 77 μg/L, respectively. Antimony, iron, lead, and manganese were the only TAL metals detected in groundwater at concentrations in excess of State or Federal screening standards. Iron and manganese detections exceeded applicable State standards among 19 and 15 shallow groundwater samples, respectively; but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. Only one positive detection of both antimony and lead exceeded applicable State standards.

1.7.6 Prevalence of Inorganic Analytes in Site Media

Inorganic analytes were detected in each soil and groundwater sample obtained during the RI field investigation at Site 86. Analytes such as arsenic, iron, and lead were principal contributors to both human health and ecological site risks. These and other inorganic analytes naturally occur, often abundantly, in site media. No discernible pattern of analyte distribution was evident among the various media sampled and former site operations do not appear to have contributed to the presence or frequency of these analytes. The natural abundance and broad distribution of inorganic analytes throughout environmental media make remediation of those analytes contributing to site risk unrealistic and impractical.

1.8 References

Baker Environmental, Inc. December 1994. Remedial Investigation/Feasibility Study Project Plans for Operable Unit No. 6 (Sites 36, 43, 44, 54, and 86), Marine Corps Base Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia.

Baker Environmental, Inc. May 1995. Site Management Plan for Marine Corps Base Camp Lejeune, North Carolina. Draft. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia.

Baker Environmental, Inc. August 1996. Remedial Investigation Report, Operable Unit No. 6 (Site 86), Marine Corps Base Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia.

Baker Environmental, Inc. November 1997. Post Remedial Investigation Field Investigative Letter Report. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia.

Cardinell, A.P., Berg, S.A., and Lloyd, O.B. 1993. Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina: U.S. Geological Survey Water Resources Investigation Report. Report No. 93-4049.

O'Brien & Gere, Inc. June 1992. Site Assessment of Tanks AS419 - AS421, Marine Corps Air Station, New River, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. Project No. 62470-90-R-7626.

Federal Facilities Agreement (FFA) between USEPA Region IV; NC DENR; and U.S. Department of the Navy, for MCB, Camp Lejeune and MCAS, New River, North Carolina. December 1989.

USEPA, United States Environmental Protection Agency. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. Office of Emergency and Remedial Response, Washington, D.C. USEPA/860/G-89004.

SECTION 1.0 TABLES

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Surface Soil	Volatiles	Toluene	NA	NA	25	25	86-GW18DW	1/18	former tank area
		Xylene (total)	NA	NA	5	5	AST-SB02	1/18	former tank area
	Semivolatiles	Naphthalene (PAH)	NA	NA	85	85	AST-SB11	1/18	former tank area
		2-Methylnapthalene	NA	NA	80	80	AST-SB11	1/18	former tank area
		Acenaphthene (PAH)	NA	NA	50	580	AST-SB11	4/18	scattered
		Dibenzofuran	NA	NA	220	220	AST-SB11	1/18	former tank area
		Fluorene (PAH)	NA	NA	43	440	AST-SB11	3/18	scattered
		Phenanthrene (PAH)	NA	NA	64	2,700	AST-SB11	8/18	scattered
		Anthracene (PAH)	NA	NA	43	790	AST-SB11	5/18	scattered
		Carbazole	NA	NA	39	480	AST-SB11	5/18	scattered
		Fluoranthene (PAH)	NA	NA	39	3,500	AST-SB11	9/18	scattered
		Pyrene (PAH)	NA	NA	110	3,100	AST-SB11	10/18	scattered
		Butyl benzyl phthalate	NA	NA	49	380	AST-SB03	4/18	former tank area
		B(a)anthracene (PAH)	NA	NA	70	2,100	AST-SB11	10/18	scattered
		Chrysene (PAH)	NA	NA	86	2,100	AST-SB11	9/18	scattered
		B(b)fluoranthene (PAH)	NA	NA	110	2,300	AST-SB11	8/18	scattered
		B(k)fluoranthene (PAH)	NA	NA	57	950	AST-SB11	8/18	scattered
		Benzo(a)pyrene (PAH)	NA	NA	48	1,800	AST-SB11	10/18	scattered
		I(1,2,3-cd)pyrene (PAH)	NA	NA	67	1,100	AST-SB11	7/18	scattered
		D(a,h)anthracene (PAH)	NA	NA	37	290	AST-SB11	4/18	former tank area
		B(g,h,i)perylene (PAH)	NA	NA	57	590	86-GW19DW	7/18	scattered

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Surface Soil (Continued)	Pesticides	Aldrin	NA	NA	2	2	86-GW18DW	1/11	former tank area
		Heptachlor epoxide	NA	NA	5.2	5.2	86-GW19DW	1/11	southeast
		Dieldrin	NA	NA	4.8	44	AST-SB01	10/11	widely scattered, prevalent
		4-4'-DDE	NA	NA	4.9	38	86-GW19DW	11/11	widely scattered, prevalent
		4-4'-DDD	NA	NA	5.2	9.6	AST-SB08	5/11	scattered
		4-4'-DDT	NA	NA	4.3	27	AST-SB08	10/11	widely scattered, prevalent
	PCBs	ND	NA	NA				0/11	
	Metals (1)	Arsenic	NA	1.3	0.5	1.8	AST-SB08	9/11	2 exceed BB, former tank area
		Cadmium	NA	0.7	0.5	1.1	86-GW18DW	5/11	2 exceed BB, former tank area
		Chromium	NA	6.7	5.1	10.1	AST-SB08	11/11	8 exceed BB, former tank area
		Copper	NA	7.2	1.1	53.4	86-GW18DW	10/11	3 exceed BB, former tank area
		Lead	NA	23.7	12.4	43.1	AST-SB03	11/11	5 exceed BB, former tank area
		Mercury	NA	0.1	0.2	0.2	86-GW19DW	1/11	1 exceeds BB, southeast
		Nickel	NA	3.4	1.3	22.3	86-GW19DW	8/11	7 exceed BB, former tank area
		Zinc	NA	13.9	5.4	39.9	86-GW18DW	11/11	6 exceed BB, former tank area
Subsurface Soil	Volatiles	Carbon Disulfide	NA	NA	3	3	WA-SB01	1/23	south of former tank area
		Toluene	NA	NA	250	250	86-GW18DW	1/23	former tank area
		Xylene (total)	NA	NA	5	5	AST-SB07	2/23	former tank area
	Semivolatiles	Fluoranthene (PAH)	NA	NA	62	62	86-GW19DW	1/23	southeast
		Pyrene (PAH)	NA	NA	57	57	86-GW19DW	1/23	southeast
		Butylbenzylphtalate	NA	NA	73	300	AST-SB11	4/23	former tank area
		Chrysene (PAH)	NA	NA	42	140	AST-SB04	2/23	former tank area
		B(b)fluoranthene (PAH)	NA	NA	43	43	86-GW19DW	1/23	southeast

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Subsurface Soil (Continued)	Pesticides	4,4'-DDE	NA	NA	1.5	20	AST-SB04	5/16	scattered
		4,4'-DDD	NA	NA	3.2	36	86-GW17IW	5/16	scattered
		4,4'-DDT	NA	NA	1.5	1.5	AST-SB04	1/16	former tank area
	PCBs	ND	NA	NA				0/16	
	Metals (1)	Antimony	NA	6.4	2.2	2.2	86-GW17IW	1/12	does not exceed BB
		Arsenic	NA	1.9	0.3	2.4	AST-SB07	13/16	2 exceed BB, former tank area
		Chromium	NA	12.6	2.4	34.4	AST-SB06	16/16	9 exceed BB, scattered
		Copper	NA	2.4	0.6	7.1	AST-SB04	14/16	5 exceed BB, former tank area
		Lead	NA	8.3	3	16.6	AST-SB06	16/16	12 exceed BB, scattered
		Nickel	NA	3.7	1	28.2	AST-SB05	12/16	4 exceed BB, former tank area
		Zinc	NA	6.7	1.3	7.9	AST-SB06	15/16	2 exceed BB, former tank area
Groundwater	Volatiles	1,1-Dichloroethane	NCWQS - 700	NA	10	14	86-GW10IW	2/41	do not exceed standard
		1,2-Dichloroethene (total)	MCL - 70	NA	3	140	86-GW15IW	14/41	2 exceed standard, southeast
		Trichloroethene	NCWQS - 2.8	NA	2	400	86-GW20IW	13/41	12 exceed standard, south and central
		Benzene	NCWQS -1	NA	2	8	86-GW15IW	7/41	7 exceed standard, south and central
		Tetrachloroethene	NCWQS - 0.7	NA	1	77	86-GW10IW	4/41	4 exceed standard, south and central
	Semivolatiles	Naphthalene (PAH)	NCWQS - 21	NA	6	6	86-GW10IW	1/23	does not exceed standard, southeast
		Dibenzofuran	NA	NA	1	1	86-GW07	1/23	north of former tank area
		Fluorene (PAH)	NCWQS - 280	NA	2	2	86-GW07	1/23	does not exceed standard, north
		Di-n-butylphthalate	NCWQS - 700	NA	23	23	86-GW17IW	1/23	does not exceed standard, west
	Pesticides	ND	NA	NA				0/5	
	PCBs	ND	NA	NA				0/5	

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Groundwater (Continued)	Total Metals	Antimony	MCL - 6	NA	23.6	23.6	86-GW16DW	1/26	1 exceeds standard, east
		Iron	NCWQS - 300	NA	5.1	68,300	86-GW07	23/26	19 exceed standard, scattered
		Lead	NCWQS - 15	NA	28.3	28.3	86-GW06IW	1/26	1 exceeds standard, tank area
		Manganese	NCWQS - 50	NA	3.8	416	86-GW17IW	22/26	15 exceed standard, scattered

Notes:

- Concentrations are presented in µg/L for liquid and µg/Kg for solids (ppb), metal concentrations for soils and sediments are presented in mg/Kg (ppm).

(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for priority pollutant metals only (i.e., antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc).

ARAR - Applicable or Relevant and Appropriate Requirements
BB - Base background, value equals two times average
NA - Not applicable
NCWQS - North Carolina Water Quality Standard
ND - Not detected
NOAA - National Oceanic and Atmospheric Administration
MCL - Federal Maximum Contaminant Level
PAH - Polynuclear aromatic hydrocarbon

TABLE 1-2

GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TCL ORGANICS

LOCATION	86-GW01-01	86-GW02IW-01	86-GW03-01	86-GW04IW-01	86-GW05-01	86-GW06IW-01	86-GW07-01
DATE SAMPLED	03/25/95	03/25/95	03/23/95	03/23/95	03/24/95	03/24/95	03/25/95
VOLATILES (ug/l)							
1,1-DICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	10 U	10 U	19	10 U	10 U	10 U
TRICHLOROETHENE	10 U	10 U	10 U	24	10 U	10 U	10 U
BENZENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
TETRACHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)							
NAPHTHALENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
DIBENZOFURAN	10 U	10 U	10 U	10 U	10 U	10 U	1 J
FLUORENE	10 U	10 U	10 U	10 U	10 U	10 U	2 J
DI-N-BUTYLPHTHALATE	10 U	10 U	10 U	10 U	10 U	10 U	10 U

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TCL ORGANICS

LOCATION	86-GW08IW-01	86-GW09-01	86-GW10IW-01	86-GW11-01	86-GW12IW-01	86-GW13-01	86-GW14IW-01
DATE SAMPLED	03/24/95	03/23/95	03/24/95	03/23/95	03/23/95	03/23/95	03/22/95
VOLATILES (ug/l)							
1,1-DICHLOROETHANE	10 U	10 U	14	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	10 U	23	10 U	10 U	10 U	10 U
TRICHLOROETHENE	10 U	10 U	27	10 U	10 U	10 U	10 U
BENZENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
TETRACHLOROETHENE	10 U	10 U	77	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)							
NAPHTHALENE	10 U	10 U	6 J	9 U	10 U	10 U	10 U
DIBENZOFURAN	10 U	10 U	10 U	9 U	10 U	10 U	10 U
FLUORENE	10 U	10 U	10 U	9 U	10 U	10 U	10 U
DI-N-BUTYLPHTHALATE	10 U	10 U	10 U	9 U	10 U	10 U	10 U

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TCL ORGANICS

LOCATION	6-GW15DW-01	86-GW15IW-01	86-GW16DW-01	86-GW16IW-01	86-GW17DW-01	86-GW17IW-01	86-GW18DW-01
DATE SAMPLED	03/21/95	03/22/95	03/20/95	03/22/95	03/21/95	03/23/95	03/22/95
VOLATILES (ug/l)							
1,1-DICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	73	10 U	10 U	10 U	10 U	10 U
TRICHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZENE	10 U	8	10 U	10 U	10 U	10 U	10 U
TETRACHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)							
NAPHTHALENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
DIBENZOFURAN	10 U	10 U	10 U	10 U	10 U	10 U	10 U
FLUORENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
DI-N-BUTYLPHTHALATE	10 U	10 U	10 U	10 U	10 U	23	10 U

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TCL ORGANICS

LOCATION	6-GW19DW-01	86-GW20IW-01	86-GW21IW-01	86-GW22IW-01	86-GW23IW-01
DATE SAMPLED	03/26/95	04/11/95	05/07/95	05/07/95	05/07/95
VOLATILES (ug/l)					
1,1-DICHLOROETHANE	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	24 J	3 J	10 UJ	10 UJ
TRICHLOROETHENE	10 U	190	10 U	10 U	10 U
BENZENE	10 U	10 U	2 J	10 U	10 U
TETRACHLOROETHENE	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)					
NAPHTHALENE	10 U	10 U	NA	NA	NA
DIBENZOFURAN	10 U	10 U	NA	NA	NA
FLUORENE	10 U	10 U	NA	NA	NA
DI-N-BUTYLPHTHALATE	10 U	10 U	NA	NA	NA

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TAL METALS

LOCATION	86-GW01-01	86-GW02IW-01	86-GW03-01	86-GW04IW-01	86-GW05-01	86-GW06IW-01	86-GW07-01
DATE SAMPLED	03/25/95	03/25/95	03/23/95	03/23/95	03/24/95	03/24/95	03/25/95
ANALYTES (ug/l)							
ALUMINUM, TOTAL	101 U	106 U	815	31.6 U	41.3 U	96.5 U	24 U
ANTIMONY, TOTAL	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U
ARSENIC, TOTAL	38.8	1.9 U	1.9 U	1.9 UJ	33	1.9 UJ	17
BARIUM, TOTAL	14.6 U	10.4 U	35.4	5.2 U	16.3 U	5.8 U	20.6 U
CALCIUM, TOTAL	937	80400	8250	80100	1270	25600	10400
IRON, TOTAL	42300	8070	281	5860	30400	4130	68300
LEAD, TOTAL	1 U	1 U	1 U	1 U	1 U	28.3	1 U
MAGNESIUM, TOTAL	1080	2360	1580	3270	2600	1860	3390
MANGANESE, TOTAL	3.8	74	14	82.7	6.2	57.5	6.8
POTASSIUM, TOTAL	685 U	2650	927	2540	717	2360	769
SELENIUM, TOTAL	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U
SODIUM, TOTAL	36800	10600	10400	12100	28900	8730	16000
VANADIUM, TOTAL	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U
ZINC, TOTAL	3.8 U	3.8 U	3.8 U	3.8 U	3.8 U	3.8 U	3.8 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TAL METALS

LOCATION	86-GW08IW-01	86-GW09-01	86-GW10IW-01	86-GW11-01	86-GW12IW-01	86-GW13-01	86-GW14IW-01
DATE SAMPLED	03/24/95	03/23/95	03/24/95	03/23/95	03/23/95	03/23/95	03/22/95
ANALYTES (ug/l)							
ALUMINUM, TOTAL	37.1 U	187	166 U	129 U	85.9 U	197 U	26.1 U
ANTIMONY, TOTAL	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U	20.7 U
ARSENIC, TOTAL	1.9 U	1.9 U	1.9 UJ	1.3 U	1.9 U	1.3 U	1.3 U
BARIUM, TOTAL	34.7	44.5	4.2 U	27	24.6	43.2	14.1 U
CALCIUM, TOTAL	145000	5340	26300	72700	20100	28200	106000
IRON, TOTAL	12000	257	9270	12300	8810	1310	6940
LEAD, TOTAL	1 U	1 U	1 U	1.6 U	1 U	1.6 U	1.6 U
MAGNESIUM, TOTAL	3130	762	6570	17300	3780	2770	1900
MANGANESE, TOTAL	74.6	7.9	114	282	72.5	25.4	55.1
POTASSIUM, TOTAL	2620	989	2310	19100	3080	2360	2150
SELENIUM, TOTAL	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U	1.5 U
SODIUM, TOTAL	14200	7420	31400	19700	28500	5340	6640
VANADIUM, TOTAL	2.3 U	2.3 U	2.3 U	100	2.3 U	2.3 U	2.4 U
ZINC, TOTAL	3.8 U	3.8 U	3.8 U	3.8 U	32.1	3.8 U	3.8 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TAL METALS

LOCATION	6-GW15DW-01	86-GW15IW-01	86-GW16DW-01	86-GW16IW-01	86-GW17DW-01	86-GW17IW-01	86-GW18DW-01
DATE SAMPLED	03/21/95	03/22/95	03/20/95	03/22/95	03/21/95	03/23/95	03/22/95
ANALYTES (ug/l)							
ALUMINUM, TOTAL	136 U	32.6 U	148 U	29.9 U	30.6 U	197 U	87.1 U
ANTIMONY, TOTAL	20.7 U	20.7 U	23.6	20.7 U	20.7 U	20.7 U	20.7 U
ARSENIC, TOTAL	5.7	1.3 U	3.7	1.3 U	1.3 U	1.3 U	3
BARIUM, TOTAL	9.3 U	15.5 U	9.7 U	17 U	12.3 U	38.1	3.4 U
CALCIUM, TOTAL	47900	70300	51800	91900	32700	112000	34100
IRON, TOTAL	78 U	1020	165	773	47.3 U	2520	78.6 U
LEAD, TOTAL	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
MAGNESIUM, TOTAL	3220	2180	2980	3930	6130	3930	5440
MANGANESE, TOTAL	9.7 U	107	18	352	3.9 U	416	8.4 U
POTASSIUM, TOTAL	6510	1680	7150	2600	15400	1800	12700
SELENIUM, TOTAL	1.5 U	1.5 U	1.6	1.5 U	1.5 U	1.5 U	1.5 U
SODIUM, TOTAL	27900	7100	53000	33900	98200	15000	90200
VANADIUM, TOTAL	6.8 U	2.3 U	11.7 U	3.9 U	2.4 U	2.7 U	4 U
ZINC, TOTAL	11.5 J	38.7 J	20.7 J	15.1 J	12.1 J	3.9 J	12.2 J

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
SITE 86, TANK AREA AS-419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA
TAL METALS

LOCATION	6-GW19DW-01	86-GW20IW-01	86-GW21IW-01	86-GW22IW-01	86-GW23IW-01
DATE SAMPLED	03/26/95	04/11/95	05/07/95	05/07/95	05/07/95
ANALYTES (ug/l)					
ALUMINUM, TOTAL	16.8 U	15.7 U	21.2 U	21.2 U	21.2 U
ANTIMONY, TOTAL	10.9 U	12 U	20.8 U	20.8 U	20.8 U
ARSENIC, TOTAL	2.5	1.7 U	1.7 U	1.7 U	1.7 U
BARIUM, TOTAL	8.6	18.8	23.9	11.4	12.7
CALCIUM, TOTAL	41800	75700	75600	58200	55300
IRON, TOTAL	5.1	1300	884	511	577
LEAD, TOTAL	1.6 U	0.8 U	0.8 UJ	0.8 UJ	0.8 UJ
MAGNESIUM, TOTAL	4130	2760	3310	2440	2960
MANGANESE, TOTAL	4.3 U	101	131	82.6	88.4
POTASSIUM, TOTAL	8230	1950	2610 J	2350 J	2070 J
SELENIUM, TOTAL	1.5 U	1.8 U	1.8 U	2 J	1.8 J
SODIUM, TOTAL	49900	10900	25500	11800	25900
VANADIUM, TOTAL	2.8 U	1.5 U	2 U	2 U	2 U
ZINC, TOTAL	1.9 U	5.2 U	6 U	6 U	6 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-4

POST-RI GROUNDWATER-VOLATILE ORGANICS
SITE 86, TANK AREA AS419-AS421
NORTH CAROLINA

SAMPLE ID	IR86-GW28IW-01	IR86-GW29IW-01	IR86-GW30IW-01	IR86-GW16IW-97C	UST428-GW06-97C	IR86-GW29IW-97C	IR86-GW31IW-97C
DATE SAMPLED	07/01/97	07/01/97	07/01/97	9/7/97	9/7/97	9/17/97	9/17/97
VOLATILES (ug/L)							
CHLOROMETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
BROMOMETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
VINYL CHLORIDE	10 U	10 U	10 U	10 U	10 U	2 J	10 U
CHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
METHYLENE CHLORIDE	10 U	10 U	10 U	2 JB	2 JB	22 BJD	2 JB
ACETONE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CARBON DISULFIDE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-DICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	56	10 U	3 J	3 J	67 D	2 J
CHLOROFORM	10 U	10 U	10 U	10 U	50	10 U	10 U
1,2-DICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-BUTANONE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-TRICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CARBON TETRACHLORIDE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
BROMODICHLOROMETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROPROPANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CIS-1,3-DICHLOROPROPENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
TRICHLOROETHENE	10 U	600	10 U	2 J	2 J	700 D	9 J
DIBROMOCHLOROMETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-TRICHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
BENZENE	10 U	10 U	10 U	10 U	3 J	10 U	10 U

NOTES

U = Not detected

J = Estimated Value

B = Detected in Blank

D = Sample dilution required

ug/L = micrograms per liter

TABLE 1-4

POST-RI GROUNDWATER-VOLATILE ORGANICS
SITE 86, TANK AREA AS419-AS421
NORTH CAROLINA

SAMPLE ID	IR86-GW28IW-01	IR86-GW29IW-01	IR86-GW30IW-01	IR86-GW16IW-97C	UST428-GW06-97C	IR86-GW29IW-97C	IR86-GW31IW-97C
DATE SAMPLED	07/01/97	07/01/97	07/01/97	9/7/97	9/7/97	9/17/97	9/17/97
VOLATILES (ug/L) (cont)							
TRANS-1,3-DICHLOROPROPENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
BROMOFORM	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-METHYL-2-PENTANONE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-HEXANONE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
TETRACHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
TOLUENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
CHLOROBENZENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ETHYLBENZENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
STYRENE	10 U	10 U	10 U	10 U	10 U	10 U	10 U
XYLENE (TOTAL)	10 U	10 U	10 U	10 U	10 U	10 U	10 U

NOTES
U = Not detected
J = Estimated Value
B = Detected in Blank
D = Sample dilution required
ug/L = micrograms per liter

TABLE 1-5

SUMMARY OF CURRENT POTENTIAL HUMAN HEALTH RISKS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Potential Human Receptor	Potential Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Military	**Surface Soil**		
	Ingestion	2.8E-02	5.5E-07
	Dermal Contact	6.7E-03	3.8E-07
	Inhalation	–	4.0E-10
	Total Risk	3.5E-02	9.3E-07
Child Trespasser	**Surface Soil**		
	Ingestion	6.9E-02	2.0E-06
	Dermal Contact	7.5E-03	6.4E-07
	Inhalation	–	6.9E-10
	Total Risk	7.6E-02	2.6E-06
Adult Trespasser	**Surface Soil**		
	Ingestion	2.4E-03	3.5E-07
	Dermal Contact	1.3E-03	5.7E-07
	Inhalation	–	3.4E-10
	Total Risk	3.8E-03	9.2E-07

Notes:

-- = Not Applicable

TABLE 1-6

SUMMARY OF FUTURE POTENTIAL HUMAN HEALTH RISKS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCAS, NEW RIVER, NORTH CAROLINA

Potential Human Receptor	Potential Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Child Resident	**Subsurface Soil**		
	Ingestion	7.2E-01	3.3E-06
	Dermal Contact	4.2E-02	1.9E-07
	Inhalation	–	1.2E-09
	Total	7.6E-01	3.5E-06
	Groundwater		
	Ingestion	**18**	5.8E-05
	Dermal Contact	2.4E-01	1.1E-06
	Inhalation	1.8E-01	1.3E-06
	Total	**19**	6.1E-05
	Future Risk	**20**	6.4E-05
Adult Resident	**Subsurface Soil**		
	Ingestion	7.7E-02	1.8E-06
	Dermal Contact	2.2E-02	5.1E-07
	Inhalation	–	2.7E-09
	Total	1.0E-01	2.3E-06
	Groundwater		
	Ingestion	**7.9**	**1.2E-04**
	Dermal Contact	1.2E-01	2.8E-06
	Inhalation	2.9E-02	1.1E-06
	Total	**8.0**	**1.3E-04**
	Future Risk	**8.1**	**1.3E-04**
Construction Worker	**Subsurface Soil**		
	Ingestion	9.5E-02	7.2E-08
	Dermal Contact	4.3E-03	3.2E-09
	Inhalation	–	2.3E-11
	Future Risk	1.0E-01	7.5E-08

Notes:

-- = Not Applicable
Bolded values indicate risk values that exceed the acceptable risk value of 1.0 for noncarcinogenic effects and 1.0×10^{-4} for carcinogenic effects.

SECTION 1.0 FIGURES

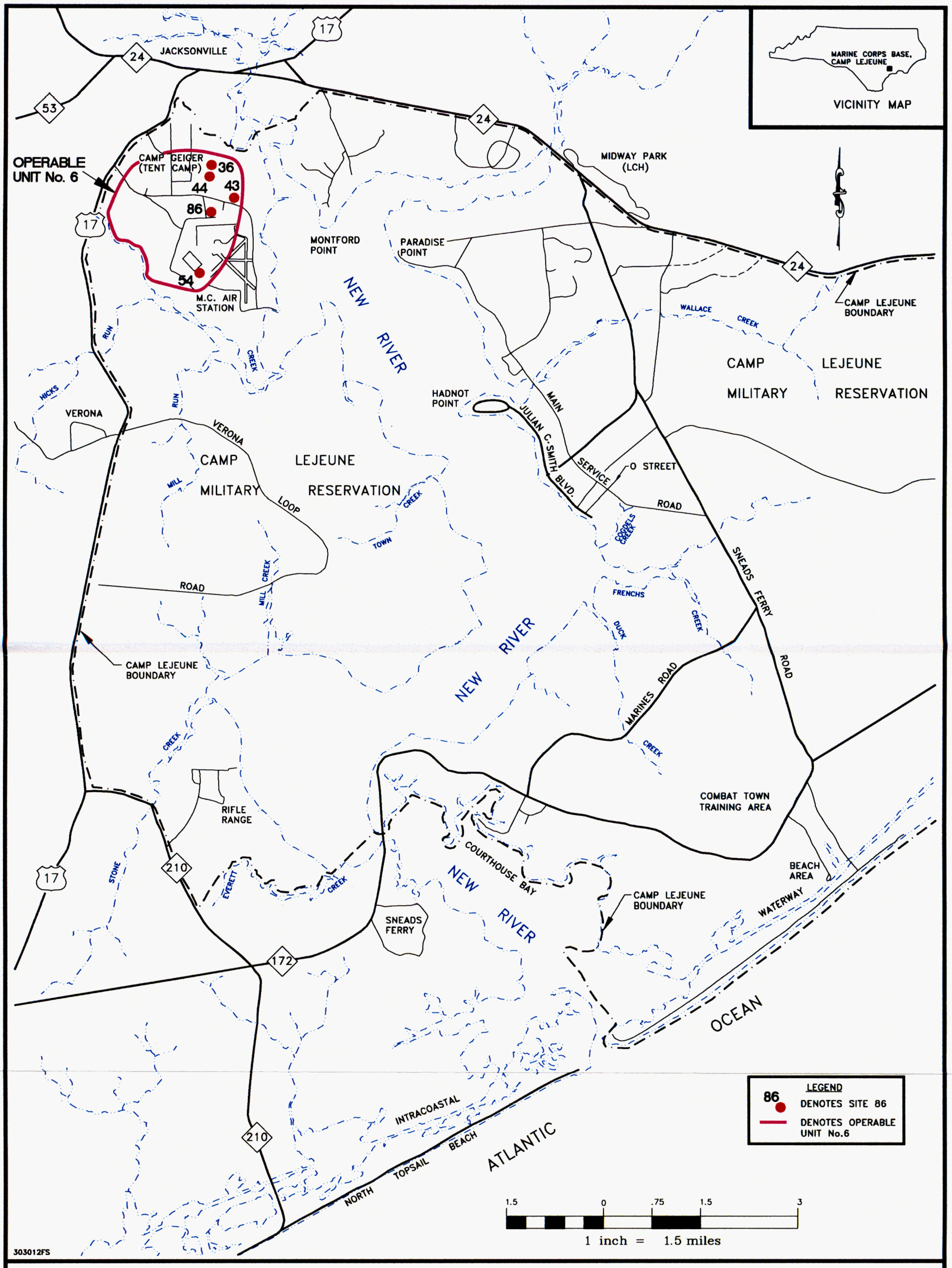
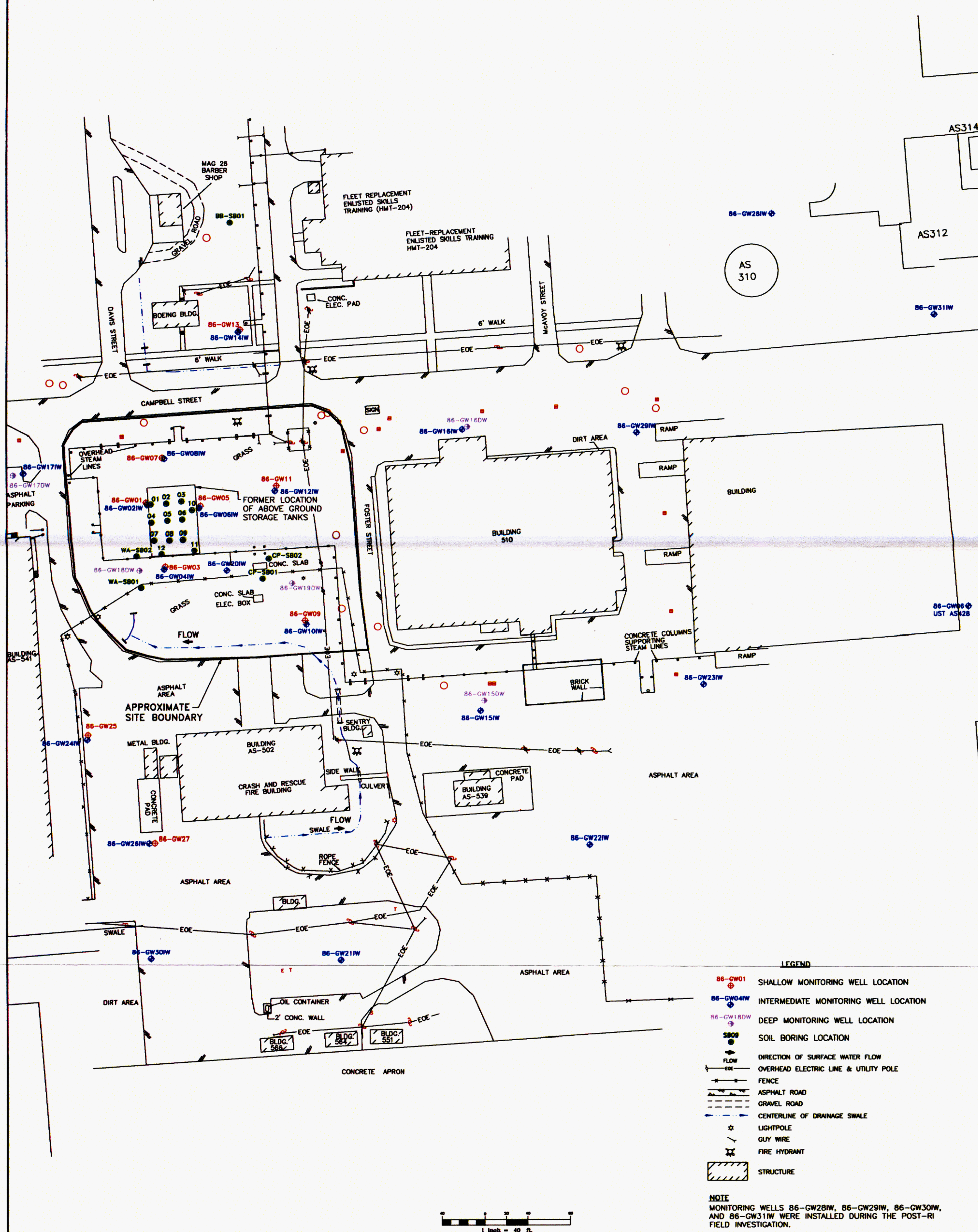


FIGURE 1-1
OPERABLE UNIT No. 6 – SITES 36, 43, 44, 54, AND 86
FEASIBILITY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02644 OBLY



SOURCE: LANTDIV, FEBRUARY 1992
SURVEY: BRENT A. LANIER AND ASSOCIATES, 1995

DRAWN: REL | REVIEWED: TFT | E.O.# 62470-303 | CADD# 303014FS

FEASIBILITY STUDY, CTO-0303
MARINE CORPS AIR STATION, NEW RIVER
NORTH CAROLINA

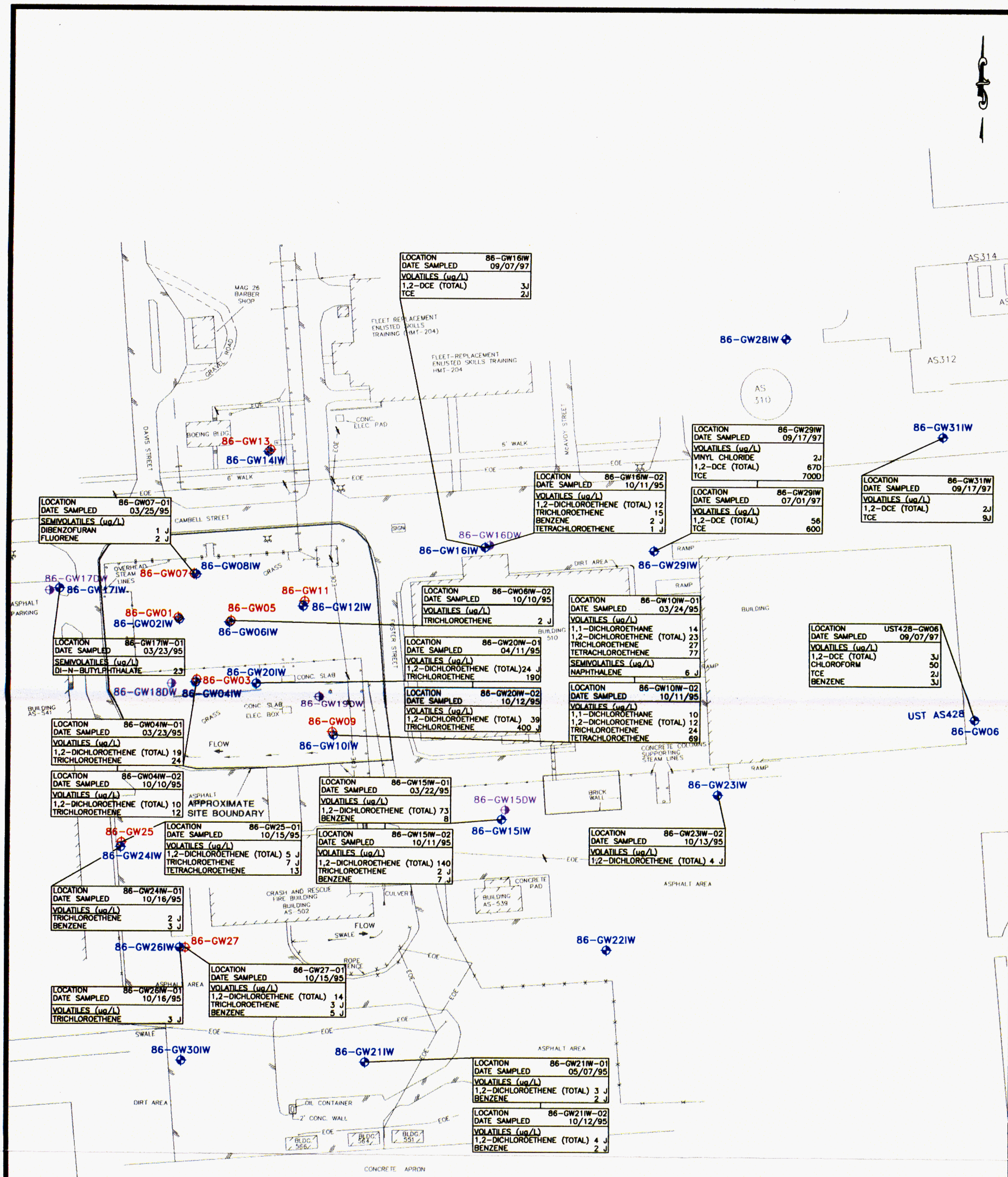
BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

REMEDIAL INVESTIGATION
SAMPLING LOCATIONS
SITE 86, TANK AREA AS-419-AS421 AT MCAS

SCALE 1"= 40' | DATE JUNE 1996

FIGURE No. 1-2



NOTES:

1. LOCATIONS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.
2. MONITORING WELLS 86-GW28IW, 86-GW29IW, 86-GW30IW AND 86-GW31IW WERE INSTALLED DURING THE POST-RI FIELD INVESTIGATION.

303016FS

LEGEND

86-GW01	SHALLOW MONITORING WELL
86-GW04IW	INTERMEDIATE MONITORING WELL
86-GW18DW	DEEP MONITORING WELL
FLOW	DIRECTION OF SURFACE WATER FLOW
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE
	ASPHALT ROAD
	CENTERLINE OF DRAINAGE SWALE
	LIGHTPOLE
	STRUCTURE
	GRAVEL ROAD
	FENCE
	GUY WIRE
	FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991

100 0 50 100

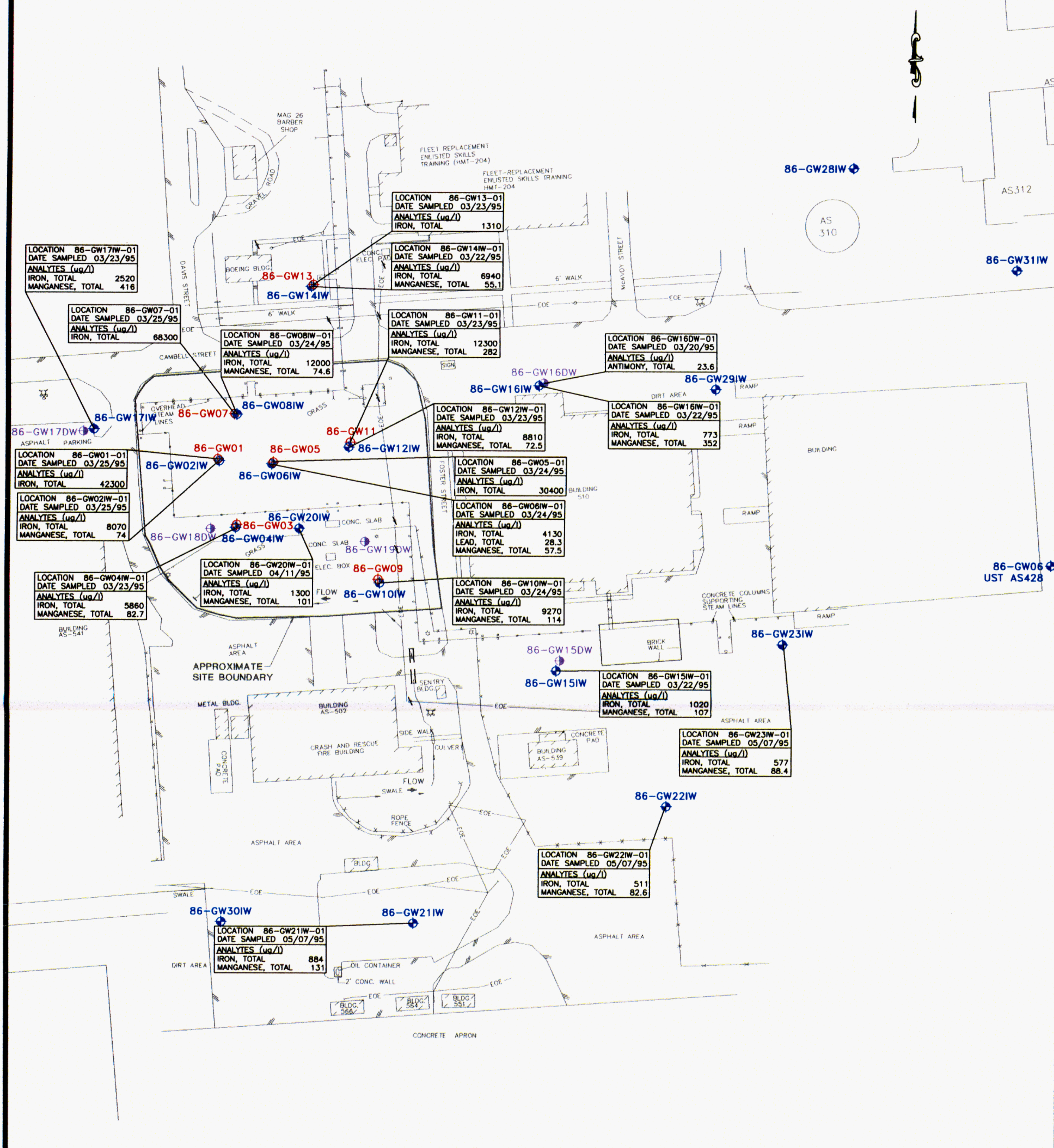
1 inch = 100 ft.

Baker

Baker Environmental, Inc.

FIGURE 1-3
ORGANIC COMPOUNDS IN GROUNDWATER
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE



NOTE:
MONITORING WELLS 86-GW28IW, 86-GW29IW, 86-GW30IW, AND 86-GW31IW WERE INSTALLED DURING THE POST-RI FIELD INVESTIGATION.

303018FS

LEGEND

86-GW01	SHALLOW MONITORING WELL		
86-GW04IW	INTERMEDIATE MONITORING WELL		
86-GW18DW	DEEP MONITORING WELL		
FLOW	DIRECTION OF SURFACE WATER FLOW		
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE		
	ASPHALT ROAD		GRAVEL ROAD
	CENTERLINE OF DRAINAGE SWALE		FENCE
	LIGHTPOLE		GUY WIRE
	STRUCTURE		FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991

100 0 50 100
1 inch = 100 ft.

Baker
Baker Environmental, Inc.

FIGURE 1-4
TAL METALS IN GROUNDWATER ABOVE SCREENING STANDARDS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE

2.0 REMEDIATION GOAL OPTIONS, REMEDIATION LEVELS, AND REMEDIAL ACTION OBJECTIVES - SITE 86

This section presents remediation goal options, RLs, and remedial action objectives for Site 86 in OU No. 6. Section 2.1 is an identification of the media and contaminants of concern, and Section 2.2 presents the exposure routes and receptors at Site 86. In Section 2.3, remediation goal options and final RLs are developed. Section 2.3 also includes a final set of contaminants of concern (COCs) for the FS. Based on the RLs, remedial action objectives and areas of concern are identified in Section 2.4.

2.1 Media of Concern/Contaminants of Concern

The medium of concern at Site 86 is groundwater. Exposure to groundwater generated unacceptable noncarcinogenic and carcinogenic human health risks. Calculated risks from exposure to surface soil and subsurface soil were within acceptable risk levels. Consequently, these media were not considered to be of concern from a human health standpoint.

Based on the findings of the ecological risk assessment, exposure to site contaminants in surface soil may potentially cause an adverse impact to terrestrial receptors. However, it should be noted that a large degree of uncertainty exists in the mathematical models used to generate these results. Consequently, a decrease in terrestrial vertebrate population from exposure to site-related contaminants is not expected, based on the terrestrial intake model. In addition, Site 86 is a predominantly industrial area that consists mainly of buildings, lawn, and asphalt areas. Consequently, an ecologically diverse population of terrestrial receptors is not expected to inhabit the site and should not be impacted adversely by site-related contamination. As a result, exposure to surface soil by ecological receptors was not evaluated as part of this FS.

The set of groundwater contaminants of potential concern (COPCs) evaluated during the BRA is listed on Table 2-1. The COPCs that contributed to unacceptable risks were considered preliminary COCs for this FS. These preliminary COCs included antimony, arsenic, iron, and lead. In addition, 1,2-DCE, TCE, benzene, and PCE were included as preliminary COCs in this FS. Although these four organic compounds did not generate unacceptable risks, they were included in the evaluation because their detected maximum concentrations exceeded Federal and/or State criteria.

Lead was identified as a COC in groundwater. The Federal action level, 15 μg/L (USEPA, 1994), was exceeded only at well 86-GW06IW. This exceedance does not indicate a discernable pattern of lead contamination in the site groundwater. Therefore, although lead was evaluated in this FS, it is not likely that remediation will be warranted based on this single exceedance.

Detected concentrations of the preliminary COCs will be compared to the RLs developed in Section 2.3.4 to generate a final list of COCs for this FS. Any preliminary COC that does not exceed its applicable regulatory or health based RL will be eliminated from the final list of COCs, thus eliminating it from consideration in this FS. The final set of COCs will become the basis for a set of remedial action objectives applicable to the site.

2.2 Exposure Routes and Receptors

To determine risk-based action levels in media of concern at the site, all possible exposure pathways were considered for the medium of concern. For Site 86, groundwater ingestion and dermal contact for an adult and child resident were evaluated.

Although exposure to groundwater can occur via inhalation of volatile contaminants, this exposure pathway was not included. The preliminary COCs in groundwater at this site were metals, which are not volatile. As a result, inhalation of metals in groundwater was not included in the calculation of a groundwater exposure action level.

2.3 Remediation Goal Options and RLs

Remediation goal options are established based on Federal and State criteria and risk-based action levels. Section 2.3.1 presents the definition of applicable or relevant and appropriate Federal and State requirements (ARARs) and "to be considered" (TBC) requirements. Section 2.3.2 provides an evaluation of Federal and State criteria applicable to the COCs at Site 86. Development of site-specific risk-based action levels for the COCs at Site 86 are provided in Section 2.3.3. The Federal and State criteria and risk-based action levels developed for each COC are considered remediation goal options. One remediation goal option is chosen for each COC to develop a final set of RLs for the FS.

2.3.1 Definition of Applicable or Relevant and Appropriate Federal and State Requirements and "To Be Considered" Requirements

Under Section 121(d)(1) of CERCLA, remedial actions must attain a degree of cleanup which assures protection of human health and the environment. Additionally, CERCLA remedial actions that leave any hazardous substances, pollutants, or contaminants on site must meet, upon completion of the remedial action, a level or standard of control that at least attains standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. These requirements are known as "ARARs" or applicable or relevant and appropriate requirements. ARARs are derived from both Federal and State laws. USEPA Interim Guidance (52 Fed. Reg. 32496, 1987) provides the following definition of "Applicable Requirements":

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Drinking water criteria may be an applicable requirement for a site with contaminated groundwater that is used as a drinking water source. The definition of "Relevant and Appropriate Requirements" is:

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

There are three types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include requirements which set health or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants. MCLs established under the Safe Drinking Water Act (SDWA) are examples of chemical-specific ARARs.

Location-specific ARARs set restrictions on activities based upon the characteristics of the site and/or the nearby suburbs. Examples include Federal and State siting laws for hazardous waste facilities and sites on the National Register of Historic Places.

The third classification of ARARs, action-specific, refers to requirements that set controls or restrictions on particular activities related to the management of hazardous substances, pollutants, or contaminants. RCRA regulations for closure of hazardous waste storage units, RCRA incineration standards, and pretreatment standards under the Clean Water Act (CWA) for discharges to publicly owned treatment works (POTWs) are examples of action-specific ARARs.

Subsection 121(d) of CERCLA requires that the remedial action meet a level or standard which at least attains Federal and State substantive requirements that qualify as ARARs. Federal, State, or local permits are not necessary for removal or remedial actions to be implemented on-site, but their substantive requirements or ARARs must be met. "On-site" is interpreted by the USEPA to include the areal extent of contamination and all suitable areas in reasonable proximity to the contamination necessary for implementation of the response action.

ARARs can be identified only on a site-specific basis. They depend on the detected contaminants at a site, site-specific characteristics, and particular remedial actions proposed for the site. Potential ARARs identified for Site 86 are presented in Section 2.3.2.

The preamble to the proposed rule in 40 CFR Part 300.400(g)(3) States that "advisories, criteria, or guidance TBC that do not meet the definition of ARAR may be necessary to determine what is protective or may be useful in developing Superfund remedies. The ARARs preamble described three types of TBCs: health effects information with a high degree of credibility, technical information on how to perform or evaluate site investigations or remedial actions, and policy" (USEPA, 1990).

2.3.2 Potential ARARs and TBCs Identified for Site 86

A set of chemical-specific, location-specific, and action-specific ARARs were identified and evaluated for Site 86 and are discussed below.

2.3.2.1 Chemical-Specific ARARs and TBCs

Potential chemical-specific ARARs and TBCs identified for the preliminary COCs at Site 86 are listed on Table 2-2. These ARARs/TBCs are Federal MCLs and NCWQSs applicable to groundwater. A brief description of these standards is presented below.

Federal Maximum Contaminant Levels - MCLs are enforceable standards for public water supplies promulgated under the SDWA and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. These standards are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply. As shown on Table 2-2, MCLs have been established for most of the groundwater COPCs. However, there is no Federal MCL for iron, which is a preliminary COC in groundwater. Consequently, the Federal MCL will not be applicable to use as an ARAR for iron in groundwater.

North Carolina Water Quality Standards (Groundwater) - Under the North Carolina Administrative Code (NCAC), Title 15A, Subchapter 2L, Section .0200, (15A NCAC 2L.0200) the NC DENR has established groundwater standards (NCWQSs) for three classifications of groundwater within the State: GA, GSA, and GC. Class GA waters are those groundwaters in the State naturally containing 250 milligram per liter (mg/L) or less of chloride. These waters are an existing or potential source of drinking water supply for humans. Class GSA waters are those groundwaters in the State naturally containing greater than 250 mg/L of chloride. These waters are an existing or potential source of water supply for potable mineral water and conversion to fresh water. Class GC water is defined as a source of water supply for purposes other than drinking. The NCAC T15A:02L.0300 has established sixteen river basins within the State as Class GC ground waters (15A NCAC 2L.0201 and 2L.0300). The North Carolina Drinking Water Act (130A North Carolina General Statute [NCGS] 311-327) also regulates water systems within the State that supply drinking water that may affect the public health.

The water quality standards for groundwater are the maximum allowable concentrations resulting from any discharge of contaminants to the land or water of the State, which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for its intended best usage. If the water quality standard of a substance is less than the limit of detectability, the substance shall not be permitted in detectable concentrations. If naturally occurring substances exceed the established standard, the standard will be the naturally occurring concentration as determined by the State. Substances which are not naturally occurring and for which no standard is specified are not permitted in detectable concentrations for Class GA or Class GSA groundwaters (15A NCAC 2L.0202).

The NCWQS for substances in Class GA and Class GSA groundwaters are established as the lesser of:

- Systemic threshold concentration (based on reference dose and average consumption)
- Concentration which corresponds to an incremental lifetime cancer risk of $1x10^{-6}$
- Taste threshold limit value
- Odor threshold limit value
- MCL
- National Secondary Drinking Water Standard

Note that the water quality standards for Class GA and Class GSA ground waters are the same except for chloride and total dissolved solids concentrations (15A NCAC 2L.0202).

The Class GA groundwater NCWQSs for the groundwater COCs for Site 86 are listed on Table 2-2. The NCWQS will be considered an ARAR for Site 86.

North Carolina Water Quality Standards (Surface Water) - Under NCAC, Title 15A, Subchapter 2B, Sections .0100-.0400 (15A NCAC 2B.0100 - .0400), the NC DENR has established a series of classifications and water quality standards for surface waters.

North Carolina Air Pollution Control Regulations - Under NCAC, Title 15A, Subchapter 2D, 2H.0600, 2Q (15A NCAC 2D, 2H .0600, 2Q), the NC DENR regulates ambient air quality and establishes air quality standards for hazardous air pollutants.

North Carolina Hazardous Waste Management Rules - Under NCAC, Title 15A, Subchapter 13A .0009 and .0012 (15A NCAC 13A .0009 and .0012), the NC DENR has established standards for hazardous waste that is excavated and stored or treated as part of a remedial action.

2.3.2.2 Location-Specific ARARs

Potential location-specific ARARs identified for Site 86 are listed on Table 2-3. An evaluation determining the applicability of these location-specific ARARs with respect to Site 86 is also presented and summarized on Table 2-3. Based on this evaluation, specific sections of the following location-specific ARAR may be applicable to Site 86:

- RCRA Location Requirements
- North Carolina hazardous Waste Management Rules
- North Carolina Recordation of Inactive Hazardous Substance and Waste Disposal Site Statute
- North Carolina Coastal Management

Please note that the citations listed on Table 2-3 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

2.3.2.3 Action-Specific ARARs

Action-specific ARARs are typically evaluated following the development of alternatives, since they are dependent on the type of action being considered. Therefore, at this step in the FS process, potential action-specific ARARs have only been identified, not evaluated, for Site 86. A set of potential action-specific ARARs are listed on Table 2-4. These ARARs are based on RCRA, CWA, SDWA, Department of Transportation (DOT), and NC DENR requirements. Note that the citations listed on Table 2-4 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

These ARARs will be evaluated after the remedial action alternatives have been identified for Site 86. Additional action-specific ARARs may also be identified and evaluated at that time.

2.3.3 Site-Specific Risk-Based Action Levels

In this section of the FS, site-specific risk-based action levels are developed for the preliminary COCs. The determination of derived action levels for Site 86 involves establishing acceptable human health risk criteria, determining allowable risk associated with the COCs, and back calculating media-specific concentrations for the established risk levels.

The methodology used for the derived action levels is in accordance with USEPA risk assessment guidance (USEPA, 1989; USEPA, 1991). For noncarcinogenic effects, concentrations were calculated to correspond to an hazard index (HI) of 1.0, 0.1 and 0.01. At these levels of contaminant exposure, via all significant exposure pathways for a given medium, even the most sensitive populations are unlikely to experience health effects. A 1.0 risk level was used as an end point for determining noncarcinogenic action levels for remediation. For carcinogenic effects, concentrations were calculated to correspond to $1x10^{-4}$ (one in ten thousand), $1x10^{-5}$ (one in one hundred thousand), and $1x10^{-6}$ (one in one million) estimated incremental lifetime cancer risk (ICR) over a lifetime of exposure to the carcinogen. Exposure was evaluated for all significant exposure pathways for a given medium. A $1x10^{-4}$ risk level was used as an end point for determining carcinogenic action levels for remediation. Based on the NCP (40 CFR 300.430; [USEPA, 1990]) for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an ICR between $1x10^{-4}$ and $1x10^{-6}$. Action levels are representative of acceptable incremental risks at the evaluated site based on current and probable future use of the area.

Three steps were involved in estimating the risk-based action levels for the preliminary COCs. These steps involved identifying the most significant (1) exposure pathways and routes, (2) exposure parameters, and (3) equations. The equations included calculations of total intake from a given medium and were based on identified exposure pathways and associated parameters.

2.3.3.1 Risk Evaluation Assessment

Medium-specific risk-based action levels were determined in accordance with USEPA guidance (USEPA, 1989). Reference doses (RfDs) were used to evaluate noncarcinogenic action levels, while cancer slope factors (CSFs) were used to evaluate carcinogenic action levels. These toxicity values were dermally-adjusted when evaluating the dermal contact exposure scenario.

Consistent with USEPA guidance, noncarcinogenic health effects were estimated using an average annual exposure. The action level incorporates the exposure time and/or frequency that represents the number of hours per day and the number of days per year exposure occurs. This is used with a term known as the averaging time, which converts the daily exposure to an annual exposure. Carcinogenic health effects were calculated as an incremental lifetime cancer risk, and, therefore, represent exposure duration over the course of a potentially exposed individual's lifetime (i.e., 70 years).

Estimation methods and models used in this section were consistent with current USEPA risk assessment guidance (USEPA, 1989; USEPA, 1991). Exposure estimates associated with the exposure route are presented below. Carcinogenic action levels for the future residential land use (i.e., ingestion of groundwater) were based on 6 years for a child (weighing 15 kilograms [kg] on average) and 24 years for an adult (weighing 70 kg on average). The following presents the equations and inputs used to estimate action levels.

Ingestion of Groundwater

Currently, there are no receptors exposed to groundwater. Groundwater is obtained from noncontaminated MCB, Camp Lejeune supply wells and pumped to water treatment plants. The treated water is distributed via the Base water system. However, for the purposes of calculating action levels, it is assumed that the site wells are potable and supply groundwater for public consumption. Groundwater ingestion action levels can be characterized using the following equation:

$$Cw = \frac{TR \ or \ THI * BW * ATc \ or \ ATnc * DY}{CSF \ or \ 1/RfD * EF * ED * IR}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (yr)
IR	=	ingestion rate (L/day)

Under the residential use scenario, the following input parameters were used to estimate action levels: adult residents were assumed to ingest 2 liters of water per day, 350 days per year over a 30 year exposure duration; and child residents are assumed to ingest 1 liter of water per day, 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the groundwater ingestion action levels.

Dermal Contact with Groundwater

Groundwater dermal contact action levels can be characterized using the following equation:

$$Cw = \frac{TR \ or \ THI * BW * ATc \ or \ ATnc * DY}{CSF \ or \ 1/RfD * SA * PC * ET * EF * ED * CF}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
SA	=	skin surface area (cm^2)

PC	=	chemical-specific dermal permeability constant (cm/hr)
ET	=	exposure time (0.25 hours)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (0.001L/ml)

Under the residential use scenario, the following input parameters were used to estimate action levels: adult residents were assumed have surface areas of 23,000 square centimeters (cm^2) available for dermal contact for 350 days per year over a 30 year exposure duration; and child residents are assumed to have 10,000 cm^2 available for dermal contact 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the groundwater exposure action levels.

2.3.3.2 Summary of Site-Specific Risk-Based Action Levels

Site-specific risk-based action levels were calculated from the risk evaluation assessment. These action levels represent the risk-based cleanup levels for specific media and are used in determining RLs.

Risk-based action levels were only generated for contaminants with available toxicity data. A summary of the action levels calculated for the potential exposure scenarios is presented below. Separate action levels for future adult and child residents were calculated. When applicable, both carcinogenic and noncarcinogenic action levels were determined. Calculations are provided in Appendix A of this report.

All possible routes of exposure were included when calculating the action levels. As a result, ingestion and dermal contact were assessed for groundwater exposure action levels. As explained previously, inhalation was not included in the calculations.

2.3.3.3 Comparison of Action Levels to Maximum Contaminant Concentrations in Groundwater

Generally, risk-based action levels are not required for any contaminants in a medium with a cumulative cancer risk of less than 1×10^{-6}, where an HI is less than or equal to 1.0, or where the action levels are clearly defined by ARARs. However, there may be cases where a medium or contaminant appears to meet the protectiveness criterion but contributes to the risk of another medium. In some cases, contamination may be unevenly distributed across the site resulting in hot spots (areas of high contamination relative to other areas of the site). Therefore, if the hot spot is located in an area which is visited or used more frequently, exposure to the spot should be assessed separately.

In order to decrease uncertainties in estimating the reasonable maximum exposure (RME) (i.e., the maximum exposure that is reasonably expected to occur at the site), the maximum concentration of a contaminant in a medium can be compared to the estimated action level, instead of using the concentration term (i.e., the 95th percent upper confidence limit), which is used to estimate the RME. To assess hot spot contaminants, a more conservative approach is followed. This maximum value is usually compared to the estimated risk-based action level, because, in most situations, assuming long-term contact with the maximum contaminant concentration is not reasonable.

Conclusions of the BRA indicate that the cumulative current and future baseline cancer risks associated with groundwater were not within the USEPA's acceptable risk range of $1x10^{-4}$ to $1x10^{-6}$, primarily because of the presence of iron and arsenic. A comparison between the maximum detected concentrations of these COCs and the risk-based action levels and chemical-specific ARARs is shown on Tables 2-6 and 2-7. The maximum detected concentrations of these COCs exceeded risk-based action levels and ARARs.

Identifying remedial alternatives should not rely solely on estimating risk-based action levels, especially in the event of hot spot contamination. Comparing maximum contaminant concentrations to risk-based action levels provides an upper-bound (i.e., worst case) conservative estimate, and aids in screening and identifying remedial alternatives. Risk-based action levels are not to be used solely in making final remedial decisions.

2.3.3.4 Uncertainty Analysis

Uncertainties associated with calculating risk-based action levels are summarized below. The action level estimates presented in the previous section are quantitative in nature and are highly dependent upon input accuracy. The accuracy with which input values can be quantified is critical to the degree of confidence that the decision maker has in the action levels.

Most scientific computation involves a limited number of input variables, tied together by a scenario to provide a desired output. Some action level inputs are based on literature values rather than measured values. In such cases, the degree of certainty may be expressed in terms of whether the estimate was based on literature values or measured values, and not how well defined the distribution of the input was. Some action levels are based on estimated parameters; the qualitative Statement that the action level was based on estimated inputs defines certainty in a qualitative manner.

Toxicity factors (i.e., CSFs and RfDs), have uncertainties built into the assumptions used to calculate these values. Because the toxicity factors are determined from high doses administered to experimental animals and extrapolated to low doses to which humans may be exposed, uncertainties exist. Thus, toxicity factors could either overestimate or underestimate potential effects on humans. However, because human data exists for very few chemicals, risks are based on these conservative values obtained primarily from animal studies.

In order to estimate an intake, certain assumptions must be made about exposure events, exposure durations, and the corresponding assimilation of contaminants by the receptor. Exposure factors have been generated by the scientific community and have undergone review by the USEPA. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of a limited number of individuals. In all instances, values used in the risk assessment, scientific judgements, and conservative assumptions agree with those of the USEPA. Conservative assumptions designed not to underestimate daily intakes were employed throughout this section and should error conservatively, thus adequately protecting human health and allowing establishment of reasonable cleanup goals.

2.3.4 Summary of RLs and Final COCs

RLs associated with the preliminary COCs at Site 86 are presented on Tables 2-6 and 2-7. This list was based on a comparison of chemical-specific ARARs and the site-specific risk-based action levels identified throughout Section 2.3.2 and 2.3.3. If a preliminary COC had an ARAR, the most limiting (or conservative) ARAR was selected as the RL for that contaminant. If a preliminary COC did not have an ARAR, the most conservative risk-based action level was selected as the RL.

In order to determine the final set of COCs, the maximum contaminant concentrations detected in the media of concern were compared to the RLs presented on Tables 2-6 and 2-7. The contaminants that exceeded at least one of the RLs were retained as COCs. The contaminants that did not exceed any of the RLs were no longer considered to be COCs with respect to this FS. Based on this comparison, the following COCs exceeded a RL and were retained as COCs for Site 86: 1,2-DCE, benzene, TCE, PCE, iron, lead, and antimony. The final set of COCs and the associated RLs are presented on Table 2-8. The basis for each of the RLs is also presented on Table 2-8. The maximum concentration of arsenic detected in the site groundwater was found below both the Federal and State criteria; therefore, it was not retained as a final COC for Site 86.

2.4 Remedial Action Objectives and Areas of Concern

The VOCs, 1,2-DCE, benzene, TCE, and PCE, were all detected in samples obtained from the surficial and upper portion of the Castle Hayne groundwater aquifers at Site 86 in excess of their respective Federal and/or State criteria. The maximum VOC concentrations were detected in wells situated in the central and southeastern portion of the study area; however, VOCs were also detected (at lower concentrations) in surrounding monitoring wells. The dispersion and concentrations of VOCs at Site 86 suggests that the source of contamination may have been located within or immediately adjacent to the study area, possibly the former AST area. Although these VOCs did not generate unacceptable risks, a defined area of concern was identified for Site 86. This identified area of concern is shown on Figure 2-1. Therefore, the remainder of this FS will focus on remedial alternatives which specifically address the presence of and the identified area related to VOCs in groundwater.

Objectives developed for groundwater at Site 86 include:

- Prevent future potential exposure to contaminated groundwater.

- Protect uncontaminated groundwater for future potential beneficial use.

Although antimony, iron, and lead were detected in the site groundwater at levels indicative of unacceptable risk to human receptors and were retained as final COCs, access and subsequent exposure to site groundwater is not currently viable. For this and the following reasons, antimony, iron, and lead are not addressed by the remedial action objectives developed for Site 86:

- Groundwater is not currently or anticipated to be a source of potable water at the site. In addition, residential development of this site is not anticipated. Therefore, the future risks associated with the presented exposure scenarios are over-estimated.

- The maximum levels of lead and antimony in groundwater were the only concentrations that exceeded the associated Federal criteria; however, lead exceeded its maximum level only once.

- In general, groundwater in the MCB, Camp Lejeune area is naturally rich in iron. At Site 86, there is no record of any historical use of iron. Consequently, it is assumed that iron is a naturally-occurring inorganic in groundwater, and its presence is not attributable to site operations. Iron is also an essential nutrient. The toxicity values associated with exposure to this metal are based on provisional studies, which have not been verified by USEPA.

2.5 References

Baker Environmental, Inc. 1996. Remedial investigation Report, Operable Unit No. 6 (Site 86), Marine Corps Base Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia.

Federal Emergency Management Agency (FEMA). 1987. Flood Insurance Rate Map. Onslow County, North Carolina, Community-Panel Number 370340-0340C. July 2, 1997.

LeBlond, Richard. 1991. Critical Species List - Camp Lejeune Endangered Species and Special-Interest Communities Survey. Principal Investigator.

North Carolina Department of Environment and Natural Resources. NC DENR. 1993. Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina. North Carolina Administrative Code. Title 15A. Subchapter 2L. November 8, 1993.

USEPA, 1994. United States Environmental Protection Agency. Drinking Water Regulations and Health Advisories. Office of Water. Washington, D.C. 1994.

USEPA, 1991. United States Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors" Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9285.6-03. March 25, 1991.

USEPA, 1990. United States Environmental Protection Agency. National Oil and Hazardous Substances Pollution Contingency Plan. 55 Federal Register 8665. Office of Emergency and Remedial Response. Washington, D.C. March 1990.

USEPA, 1989. United States Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/1-89-002. December 1989.

USEPA, 1987. United States Environmental Protection Agency. Interim Guidance. 52 Federal Register 32496. 1987.

SECTION 2.0 TABLES

TABLE 2-1

PRELIMINARY CONTAMINANTS OF CONCERN FOR THE FS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Media	Contaminant of Potential Concern Evaluated in the Risk Assessment[1]	Preliminary Contaminant of Concern for the FS [2]
Groundwater	**1,2-Dichloroethene (total)**	X
	Trichloroethene	X
	Benzene	X
	Tetrachloroethene	X
	Antimony	X
	Arsenic	X
	Iron	X
	Lead	X
	Vanadium	

Notes:

[1] This list includes all of the contaminants of potential concern evaluated in the risk assessment (Baker, 1996)

[2] The determination of the set of preliminary contaminants of concern for the FS was based on whether the contaminant was found to be a contaminant of concern from the results of the baseline human health risk assessment. 1,2-Dichloroethene, benzene, trichloroethene, and tetrachloroethene were detected at levels greater than Federal and/or State criteria and were evaluated.

TABLE 2-2

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs FOR GROUNDWATER COCs SITE 86, TANK AREA AS419-AS421 AT MCAS FEASIBILITY STUDY CTO-303 MCAS, NEW RIVER, NORTH CAROLINA

Preliminary Contaminant of Concern	Federal MCL (µg/L)	NCWQS (µg/L)
1,2-Dichloroethene (total)	70	NE
Benzene	5	1
Trichloroethene	5	2.8
Tetrachloroethene	5	0.7
Antimony	6	NE
Arsenic	50	50
Iron	NE	300
Lead	15	NE

Notes:

µg/L = micrograms per liter
NCWQS = North Carolina Water Quality Standards for Groundwater
MCL = Safe Drinking Water Act Maximum Contaminant Level
NE = No Criteria Established
(1) The Federal MCL for lead is the action level.

TABLE 2-3

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
National Historic Preservation Act of 1966 - requires action to take into account effects on properties included in or eligible for the National Register of Historic Places and to minimize harm to National Historic Landmarks.	16 USC 470, 40-CFR-6.301(b), and 36 CFR 800	No known historic properties are within or near Site 86; therefore, this act will not be considered as an ARAR.
Archeological and Historic Preservation Act - establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain.	16 USC 469, and 40 CFR 6.301(c)	No known historical or archeological data is known to be present at the sites; therefore, this act will not be considered as an ARAR.
Historic Sites, Buildings and Antiquities Act - requires action to avoid undesirable impacts on landmarks on the National Registry of Natural Landmarks.	16-USC 461467, and 40 CFR 6.301(a)	No known historic sites, buildings or antiquities are within or near Site 86; therefore, this act will not be considered as an ARAR.
Fish and Wildlife Coordination Act - requires action to protect fish and wildlife from actions modifying streams or areas affecting streams.	16 USC 661-666	There are no creeks, streams or rivers located near and/or within the site boundaries; therefore, this act will not be considered as an ARAR.
Federal Endangered Species Act - requires action to avoid jeopardizing the continued existence of listed endangered species or modification of their habitat.	16-USC 1531, 50 CFR 200, and 50 CFR 402	No endangered species have been sited near and on-site or referenced during the survey (LeBlond, 1994); therefore, this will not be considered as an ARAR.
North Carolina Endangered Species Act - per the North Carolina Wildlife Resources Commission. Similar to the Federal Endangered Species Act, but also includes State special concern species, State significantly rate species, and the State watch list.	GS 113-331 to 113-337	No endangered species have been sited near and on-site or referenced during the survey (LeBlond, 1994); therefore, this will not be considered as an ARAR.
Rivers and Harbors Act of 1899 (Section 10 Permit) - requires permit for structures or work in or affecting navigable waters.	33 USC 403	No rivers are within vicinity of this site; therefore, this act will not be considered as an ARAR.
Executive Order 11990 on Protection of Wetlands - establishes special requirements for Federal agencies to avoid the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.	Executive Order Number 11990, and 40-CFR-6	Based on a review of Wetland Inventory Maps, there are no wetlands present at Site 86. Therefore, this will not be an applicable ARAR.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
Executive Order 11988 on Floodplain Management - establishes special requirements for Federal agencies to evaluate the adverse impacts associated with direct and indirect development of a floodplain.	Executive Order Number 11988, and 40 CFR 6	Based on the Federal Emergency Management Agency's Flood Insurance Rate Map for Onslow County, OU No. 6 is primarily within a minimal flooding zone (outside the 500-year floodplain). The immediate areas around Site 86 are not within the 100-year floodplain (FEMA, 1987); therefore, this act will not be considered an ARAR.
Wilderness Act - requires that federally owned wilderness area are not impacted. Establishes nondegradation, maximum restoration, and protection of wilderness areas as primary management principles.	16-USC-1131, and 50-CFR-35.1	No known federally owned wilderness areas near Site 86; therefore, this act will not be considered as an ARAR.
National Wildlife Refuge System - restricts activities within a National Wildlife Refuge.	16 USC 668, and 50 CFR 27	No known National Wildlife Refuge areas near Site 86; therefore, this will not be considered as an ARAR.
Scenic Rivers Act - requires action to avoid adverse effects on designated wild or scenic rivers.	16 USC 1271, and 40 CFR 6.302(e)	No known wild or scenic rivers near Site 86; therefore, this act will not be considered as an ARAR.
Coastal Zone Management Act - requires activities affecting land or water uses in a coastal zone to certify noninterference with coastal zone management.	16-USC 1451	No activities will affect land or water uses in a coastal zone; therefore, this act will not be considered as an ARAR.
Clean Water Act (Section 404) - prohibits discharge of dredged or fill material into wetland without a permit.	33 USC 404	No actions to discharge dredged or fill material into wetlands will be considered for Site 86; therefore, this act will not be considered as an ARAR.
RCRA Location Requirements - limitations on where on-site storage, treatment, or disposal of RCRA hazardous waste may occur.	40 CFR 264.18	These requirements may be applicable if the remedial actions for the site includes the on-site storage, treatment, or disposal of RCRA hazardous waste. Therefore, these requirements may be an applicable ARAR.
North Carolina Hazardous Waste Management Rules	15A NCAC 13A.0009 and .0012	These requirements may be applicable if hazardous waste will be excavated, stored and treated on site. Therefore, these location and land disposal restriction requirements may be applicable ARARs for Site 86.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
North Carolina Solid Waste Management Rules	15A NCAC 13B.1600	A solid waste landfill facility will not be sited at Site 86. Therefore, these rules will not be considered an ARAR.
North Carolina Recordation of Inactive Hazardous Substance or Waste Disposal Sites Statutes	N.C.G.S. 130A-310.8	Site 86 is not a hazardous substance or waste disposal site. Therefore, this statute is not an ARAR for Site 86.
North Carolina Coastal Management	15A NCAC 7H	Site 86 may be in a coastal management zone. Therefore, these requirements may be applicable to Site 86.

TABLE 2-4

POTENTIAL ACTION-SPECIFIC ARARs
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Standard [1]	Action	General Citation[2]
RCRA	Capping	40 CFR 264
	Closure	40 CFR 264, 244
	Container Storage	40 CFR 264, 268
	New Landfill	40 CFR 264
	New Surface Impoundment	40 CFR 264
	Dike Stabilization	40 CFR 264
	Excavation, Groundwater Diversion	40 CFR 264, 268
	Incineration	40 CFR 264, 761
	Land Treatment	40 CFR 264
	Land Disposal	40 CFR 264, 268
	Slurry Wall	40 CFR 264, 268
	Tank Storage	40 CFR 264, 268
	Treatment	40 CFR 264, 265, 268; 42 USC 6924; 51 FR 40641; 52 FR 25760
	Waste Pile	40 CFR 264, 268
CWA	Discharge to Water of United States	40 CFR 122, 125, 136
	Direct Discharge to Ocean	40 CFR 125
	Discharge to POTW	40 CFR 403, 270
	Dredge/Fill	40 CFR 264; 33 CFR 320-330; 33 USC 403
SDWA	Underground Injection Control	40 CFR 144, 146, 147, 268
DOT	DOT Rules for Transportation	49 CFR 107
OSWER Directive	Monitored Natural Attenuation	OSWER 9200.4-17

TABLE 2-4 (Continued)

POTENTIAL ACTION-SPECIFIC ARARs
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Standard [1]	Action	General Citation[2]
NC DENR	Treated Groundwater Discharge	Title 15, Chapter 2 Section .0100
	Groundwater Corrective Action	Title 15A, Chapter 2L, Sections .0106 - .0113
	Division of Water Quality Guidance Document	Title 15A, Chapter 2L, Implementation Guidance
	Well and Injection Well Construction	Title 15A, Chapter 2C, Sections .0100 - .0200
	Water Discharge	Title 15A, Chapter 2H, Sections .0100 - .0200
	Sedimentation Control	Title 15A, Chapter 2H, Section .1000
	Hazardous Waste management	Title 15A, Chapter 13A
	Solid Waste Management	Title 15A, Chapter 13B
	Air Emission Controls	Title 15A, Chapter 2D, 2H.0600, 2Q

Notes:

(1) RCRA = Resource Conservation Recovery Act
CWA = Clean Water Act
SDWA = Safe Drinking Water Act
DOT = Department of Transportation

(2) CFR = Code of Federal Regulations

TABLE 2-5

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Input Parameter	Units	Potential Receptor	
		Future Residential Child	Future Residential Adult
Groundwater (mg/L)			
Ingestion Rate, IR	L/d	1	2
Surface Area, SA	cm^2	10,000	23,000
Exposure Frequency, EF	d/y	350	350
Exposure Duration, ED	y	6	30
Exposure Time, ET	h/d	0.25	0.25
Averaging Time, Noncarc., ATnc	d	2,190	10,950
Averaging Time, Carc., ATcarc	d	25,550	25,550
Conversion Factor, CF	L/cm^3	0.001	0.001
Body Weight, BW	kg	15	70

References:

USEPA Risk Assessment for Superfund Volume I. Human Health Manual (Part A) Interim Final, December, 1989

USEPA Exposure Factors Handbook, July, 1989

USEPA Risk Assessment for Superfund Volume I. Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors" Interim Final. March 25, 1991

USEPA Dermal Exposure Assessment: Principles and Applications. Interim Report. January, 1992

USEPA Region IV Guidance for Soil Absorbance

Notes:

mg/L = milligrams per liter
L/d = liters per day
cm^2 = square centimeters
d/y = days per year
h/d = hours per day
L/cm^3 = liters per cubic centimeters
kg = kilograms

TABLE 2-6

COMPARISON OF SITE MAXIMUM LEVEL TO CRITERIA
FUTURE ADULT RESIDENT
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Preliminary Contaminant of Concern	Maximum Detected Level (μg/L)	Noncarcinogenic Risk - Based Action Level (μg/L)(1)	Carcinogenic Risk-Based Action Level (μg/L)(2)	Federal MCL (μg/L)	NCWQS (μg/L)	Tap Water RBC (μg/L)	RL (μg/L)
1,2-Dichloroethene (1,2-DCE)	140	330	NA	70	NA	5.5	70
Benzene	8	190,000	280	1	1	0.36	1
Tetrachloroethene (PCE)	77	320	145	5	0.7	1.1	0.7
Trichloroethene (TCE)	400	210	750	5	2.8	1.6	5
Antimony	23.6	15	NA	6	NA	1.5	6
Arsenic	38.8	11	5.6	50	50	1.1/0.045 (3)	50
Iron	68,300	11,000	NA	NA	300	1,100	300
Lead	28.3	NA	NA	15	NA	NA	15

Notes:
The risk-based action levels were based on exposure to groundwater via ingestion and dermal contact. Only metals in groundwater was identified as contributing to unacceptable risks in the BRA. Consequently, the inhalation pathway was not included in the calculation of groundwater action levels for antimony, arsenic, and iron.

(1) These risk-based levels are based on a total noncarcinogenic risk of 1.0. The risk-based action levels for 1,2-DCE are 33 μg/L and 3.3 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for benzene are 19,000 μg/L and 1,900μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for PCE are 32 μg/L and 3.3 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for TCE are 21 μg/L and 2.1 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for antimony are 1.5 μg/L and 015 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for arsenic are 1.1 μg/L and 0.11 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for iron are 1,100 μg/L and 110 μg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. However, remediation is based on a total noncarcinogenic risk of 1.0.

(2) This carcinogenic risk-based level is based on a total carcinogenic risk of $1x10^{-4}$. The carcinogenic risk-based action levels for benzene are 28 μg/L and 2.8 μg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. The carcinogenic risk-based action levels for PCE are14.5 μg/L and 1.45 μg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. The carcinogenic risk-based action levels for TCE are75 μg/L and 7.5 μg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. The carcinogenic risk-based action levels for arsenic are 0.56 μg/L and 0.056 μg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. However, remediation is based on a total noncarcinogenic risk of $1x10^{-4}$.

(3) The noncarcinogenic and carcinogenic tap water RBCs for arsenic are presented, respectively.

NA = Not applicable
μg/L = Micrograms per liter
MCL - Federal Maximum Contaminant Level
NCWQS = North Carolina Water Quality Standard
RBC = USEPA Region III Risk Based Concentrations
BRA = Baseline human health risk assessment
RL = Remediation level

TABLE 2-7

COMPARISON OF SITE MAXIMUM LEVEL TO CRITERIA
FUTURE CHILD RESIDENT
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Preliminary Contaminant of Concern	Maximum Detected Level (µg/L)	Noncarcinogenic Risk - Based Action Level (µg/L)(1)	Carcinogenic Risk-Based Action Level (µg/L)(2)	Federal MCL (µg/L)	NCWQS (µg/L)	Tap Water RBC (µg/L)	RL (µg/L)
1,2-Dichloroethene (1,2-DCE)	140	0.141	NA	70	NA	5.5	70
Benzene	8	30	0.6	1	1	0.36	1
Tetrachloroethene (PCE)	77	0.14	0.31	5	0.7	1.1	0.7
Trichloroethene (TCE)	400	0.09	1.6	5	NA	1.6	5
Antimony	23.6	6.3	NA	6	NA	1.5	6
Arsenic	38.8	4.85	12	50	50	1.1/0.045(3)	50
Iron	68,300	4,850	NA	NA	300	1,100	300
Lead	28.3	NA	NA	15	NA	NA	15

Notes:
The risk-based action levels were based on exposure to groundwater via ingestion and dermal contact. Only metals in groundwater was identified as contributing to unacceptable risks in the BRA. Consequently, the inhalation pathway was not included in the calculation of groundwater action levels for antimony, arsenic, and iron.

(1) These risk-based levels are based on a total noncarcinogenic risk of 1.0. The risk-based action levels for antimony are 6.3×10^{-4} mg/L and 6.3×10^{-5} mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for arsenic are 4.85×10^{-4} mg/L and 4.85×10^{-5} mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for iron are 0.485 mg/L and 0.0485 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. However, remediation is based on a total noncarcinogenic risk of 1.0.

(2) This carcinogenic risk-based level is based on a total carcinogenic risk of 1×10^{-4}. The carcinogenic risk-based action levels are 1.2×10^{-3} mg/L and 1.2×10^{-4} mg/L for total carcinogenic risks of 1×10^{-5} and 1×10^{-6}, respectively. However, remediation is based on a total noncarcinogenic risk of 1×10^{-4}.

(3) The noncarcinogenic and carcinogenic tap water RBCs for arsenic are presented, respectively.

NA = Not applicable
µg/L = Micrograms per liter
MCL - Federal Maximum Contaminant Level
NCWQS = North Carolina Water Quality Standard
RBC = USEPA Region III Risk Based Concentrations
BRA = Baseline human health risk assessment
mg/L - Milligrams per liter
RL = Remediation level

TABLE 2-8

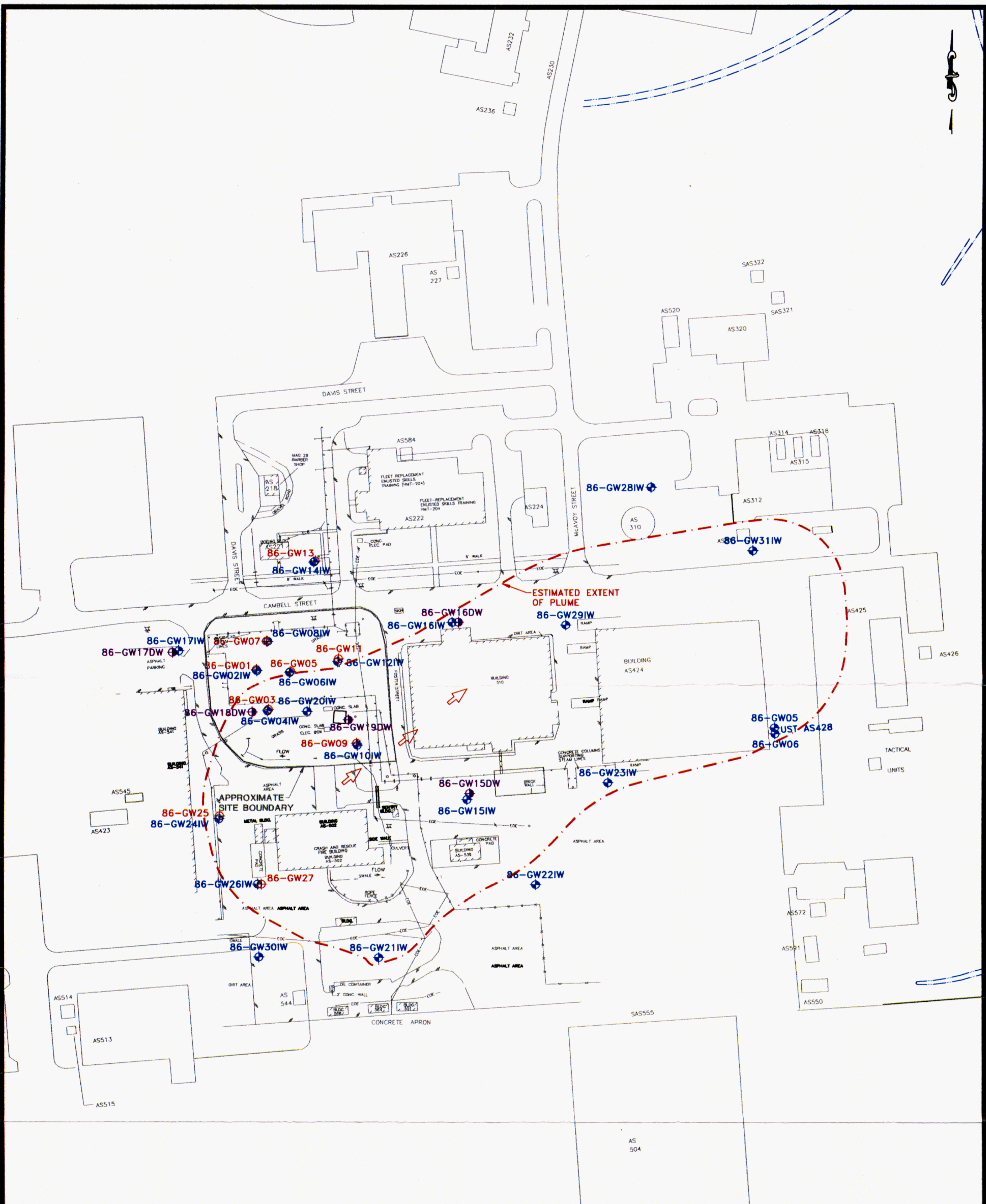
FINAL SET OF COCs and RLs
SITE 86, TANK AREA AS419 - AS421 AT MCAS
FEASIBILITY STUDY CTO-303
MCAS, NEW RIVER, NORTH CAROLINA

Contaminant of Concern	Remediation Level	Units	Basis of Remediation Level
1,2-Dichloroethene	70	μg/L	MCL
Benzene	1	μg/L	NCWQS
Tetrachloroethene	0.7	μg/L	NCWQS
Trichloroethene	5	μg/L	MCL
Antimony	6	μg/L	MCL
Iron	300	μg/L	NCWQS
Lead	15	μg/L	Federal MCL: action level in groundwater

Notes:

MCL = Maximum Contaminant Level
NCWQS = North Carolina Water Quality Standards for Groundwater
μg/L = Micrograms per liter

SECTION 2.0 FIGURES



NOTE: MONITORING WELLS 86-GW28IW, 86-GW29IW, 86-GW30IW, AND 86-GW31IW WERE INSTALLED DURING THE POST-RI FIELD INVESTIGATION.

303025FS

LEGEND

86-GW01	SHALLOW MONITORING WELL		DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE AREA OF CONCERN
86-GW04IW	INTERMEDIATE MONITORING WELL		
86-GW18DW	DEEP MONITORING WELL		GRAVEL ROAD
FLOW	DIRECTION OF SURFACE WATER FLOW		FENCE
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE		GUY WIRE
	ASPHALT ROAD		FIRE HYDRANT
	CENTERLINE OF DRAINAGE SWALE		
	LIGHTPOLE		
	STRUCTURE		

SOURCE: LANTDIV, OCT. 1991

150 0 75 150
1 inch = 150 ft.

Baker
Baker Environmental, Inc.

FIGURE 2-1
VOC AREA OF CONCERN
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE

02644C02Y

3.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Section 3.0 includes the identification and preliminary screening of remedial action technology types and process options that may be applicable to the remediation of groundwater at Site 86. More specifically, Section 3.1 identifies a set of general response actions, Section 3.2 identifies remedial action technology types and process options for each general response action, and Section 3.3 presents the preliminary screening of the remedial action technology types and process options. After the preliminary screening, the remaining technology types/process options undergo a process option evaluation in Section 3.4. The final set of remedial action technology types and a brief description of the options that passed the process option evaluation are presented in Section 3.5.

3.1 General Response Actions

General response actions are broad-based, medium-specific categories of actions that can be identified to satisfy the remedial action objectives of an FS. Five general response actions have been identified for the Site 86 remedial action objectives: no action, institutional controls, containment/collection actions, treatment actions, and discharge actions. A brief description of these general response actions follows.

3.1.1 No Action

The NCP requires the evaluation of the no action response as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that offer a greater level of response. A no action alternative may be considered appropriate when there are no adverse or unacceptable risks to human health or the environment, or when a response action may cause a greater environmental or health danger than the no action alternative.

3.1.2 Institutional Controls

Institutional controls are various "institutional" actions that can be implemented as part of a complete remedial action alternative. Institutional controls are designed to minimize exposure to potential site specific hazards. With respect to groundwater, institutional controls may include monitoring programs, access restrictions, and aquifer use restrictions.

3.1.3 Containment/Collection Actions

This general response action combines both containment and collection actions. Containment actions include technologies which contain and/or isolate contaminants by covering, sealing, chemically stabilizing, or providing an effective barrier against specific areas of concern. These actions also provide isolation and prevent direct exposure with or migration of the contaminated media. Collection actions for groundwater include technologies that collect contaminants via withdrawal techniques such as extraction or subsurface drains.

3.1.4 Treatment Actions

Treatment actions for contaminated groundwater include biological, physical/chemical, and thermal treatment, engineered wetlands, and off-site and in situ treatment systems. Treatment actions are usually followed by discharge actions.

3.1.5 Discharge Actions

Discharge actions involve the on-site and/or off-site destinations where extracted and/or treated water may be discharged. Discharge actions are usually employed after groundwater has been treated.

3.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable technologies and process options will be identified for each general response action. The term "technology type" will refer to general categories of technologies such as biological treatment, physical/chemical treatment, thermal treatment, engineered wetlands, and off-site and in situ treatment. The term "process option" will refer to specific processes, or technologies, within each generalized technology type. For example, air stripping, carbon adsorption, and reverse osmosis are process options that fall under the technology type identified as physical/chemical treatment. Several technology types may be identified for each general response action, and numerous process options may exist within each generalized technology type.

With respect to their corresponding general response action, the remedial action technology types and the associated process options that are potentially applicable at Site 86 are identified on Table 3-1.

3.3 Preliminary Screening of Remedial Action Technologies and Process Options

During the preliminary screening, the set of remedial action technology types and process options identified on Table 3-1 will be screened (or reduced) by evaluating the technology types with respect to contaminant-specific and site-specific factors. This screening step will be accomplished by using readily available information from the RI (with respect to contaminant types, contaminant concentrations, and on-site characteristics) to screen out technology types and process options that cannot be effectively implemented at the site (USEPA, 1988). In general, all technology types and process options which appear to be applicable to the site contaminants and site conditions will be retained for further evaluation. The preliminary screening for Site 86 is presented on Table 3-2.

As shown on Table 3-2, several technology types and/or process options were eliminated from further evaluation because they were determined to be inappropriate for the site-specific characteristics and/or contaminant-specific characteristics. The groundwater technology types/ process options that were eliminated include:

- Access Restrictions/Deed Restrictions
- Access Restrictions/Fencing
- Capping/Clay Soil Cap, Asphalt/Concrete Cap, Soil Cover, and Multilayered Cap
- Vertical Barriers/Grout Curtain, Slurry Wall, Sheet Piling, and Rock Grouting
- Horizontal Barriers/Grout Injection and Block Displacement
- Extracton/Extraction-Injection Wells and Hydrofracturing

- Subsurface Drains/Interceptor Trenches
- Biological Treatment/Aerobic
- Physical/Chemical Treatment/Steam Stripping, Chemical Dechlorination, Chemical Oxidation, Chemical Reduction, Reverse Osmosis, Ion Exchange, Electrolysis, Electrodialysis, Electrochemical Ion Generation, Distillation, and Oil/Water Separation
- Thermal Treatment/Liquid Injection Incineration, Molten Glass, Plasma Arc Torch, Pyrolysis, Wet Air Oxidation, and Supercritical Oxidation
- Engineered Wetland Treatment/Constructed Wetlands
- Off-site Treatment/Sewage Treatment Plant
- In Situ Treatment/Dual Phase Extraction and Passive Treatment Wall
- On-site Discharge/Reinjection

The technology types and process options that passed the preliminary screening are summarized on Table 3-3.

3.4 Process Option Evaluation

The objective of the process option evaluation is to select only one process option for each applicable remedial technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. More than one process option may be selected for a technology type if the processes are sufficiently different in their performance that one would not adequately represent the other. The representative process provides a basis for developing performance specifications during preliminary design. However, the specific process option used to implement the remedial action may not be selected until the remedial design phase.

During the process option evaluation, the process options listed on Table 3-3 were evaluated based on three criteria: effectiveness, implementability, and relative cost. The effectiveness evaluation focused on: the potential effectiveness of process options in meeting the remedial action objectives; the potential impacts to human health and the environment during the construction and implementation phase; and how reliable the process is with respect to the COCs. The implementability evaluation focused on the administrative feasibility of implementing a technology (e.g., obtaining permits), since the technical implementability was previously considered in the preliminary screening. The relative cost evaluation played a limited role in this screening. Only relative capital and operation and maintenance (O&M) costs were used instead of detailed estimates. As per the USEPA guidance, the relative cost analysis was made on the basis of engineering judgement.

A summary of the process options evaluation is presented on Table 3-4. It is important to note that the elimination of a process option does not mean that the process option can never be reconsidered for the site. As previously stated, the purpose of this part of the FS process is to simplify the development and evaluation of potential alternatives.

3.5 Final Set of Remedial Action Technologies/Process Options

Table 3-5 identifies the final set of feasible technology types and process options that will be used to develop the RAAs for Site 86. A brief description of each technology type/process option is presented below. However, prior to the descriptions of each technology type/process option a brief description of the recent investigation/evaluation of applicable hot-spot remedial action alternatives follows.

Based on the results of the post-RI field investigation and the levels of TCE detected at Site 86, an investigation/evaluation of the following hot-spot remedial actions was conducted. The initial investigation centered on electro-chemical geo-oxidation. This technology consists of the placement of electrodes that are inserted below the ground surface to remediate a variety of contaminants in soil and groundwater, including chlorinated solvents. The appropriate voltage and intensity of the current applied to the electrodes is determined by the electrical resistivity, site geology, and hydrogeology of the site being treated. The process usually takes 120 to 180 days depending on the size of the plume, and excavation is not required. Although this technology is applicable to developed areas, its use at Site 86 was considered inappropriate.

The second remedial technology considered for hot spot groundwater remediation is the Peroxide/Catalyst Injection Technology. This technology is a remediation process based on Fenton reaction chemistry which was developed by H.J.H. Fenton in the 1890s. Fenton reaction chemistry, which is widely used in the wastewater industry for treating organic wastes, oxidizes malic acid by using hydrogen peroxide and iron salts. The reaction of hydrogen peroxide and ferrous iron (Fe^{+2}) produces hydroxyl radicals, which are the second most powerful nonspecific oxidizing agents. When in the presence of chlorinated compounds, the process continues until they are degraded to carbon dioxide and water. Although this technology is innovative, recommendations and guidelines for the recommendations and guidelines for the use of this process were developed by the USEPA Region V, the State of Florida Department of Environmental Protection, and the State of Wisconsin Department of Natural Resources.

These recommendations identify the types of circumstances that may exist to hinder the use of this H_2O_2/catalyst injection. Based upon the review of the circumstances that exist at Site 86, the use of this technology was considered inappropriate.

3.5.1 No Action

The no action response provides a baseline for comparison with other response actions. Under the no action response, groundwater at Site 86 will be left in place, and natural passive remediation can occur. Passive remediation involves natural attenuation processes, such as biodegradation, volatilization, photo lysis, leaching, adsorption, and chemical reactions between subsurface materials that over time destroy contaminants. Factors that influence these natural processes include: water content in soil, soil porosity/permeability, clay content, adsorption, site density, pH, oxidation/reduction potential, temperature, wind, evaporation, precipitation, microbial community, chemical composition and concentration, depth of incorporation, irrigation management, soil management, and availability of nutrients.

3.5.2 Groundwater Monitoring

A groundwater monitoring program could be implemented at Site 86 as an institutional control or as monitored natural attenuation. Programs such as these would continue to provide information regarding the effectiveness and timing of any groundwater remedial activity conducted at the site or to monitor contaminant migration over time.

3.5.3 Restrictions in Base Master Plan

Aquifer-use restrictions could be instituted via the Base Master Plan to restrict the use of the surficial aquifer at Site 86 as a drinking water source. These restrictions would help reduce the risk to both human and ecological populations from ingestion and direct contact with the contaminants within the aquifer. To ensure that aquifer restrictions are maintained, annual certification that the restrictions in the Base Master Plan have remained unchanged and recordation of a Notice of Inactive Hazardous Substance or Waste Disposal Sites ("Notice"). Upon signature of the Record of Decision (ROD), the plat associated with the "Notice" shall be submitted for NC DENR concurrence. The RCRA Permit Modification that imposes site restrictions will be modified. Finally, in the event that the property is transferred to another party, MCB, Camp Lejeune shall state that the site has been used as a hazardous waste disposal site, and record the site restrictions and outline the responsibilities of the Navy and the transferee in the form of restrictive covenants at the Onslow County register of deeds' office prior to the transfer.

3.5.4 Extraction Wells

The extent and migration of a contaminated groundwater plume may be contained or collected via pumping techniques. Existing wells or additional extraction wells, strategically located according to the hydrogeologic characteristics of the surficial aquifer and the surficial chemical characteristics of the contaminants of concern, can be used. The extraction wells are pumped at specific rates such that the capture radius from the well system intercepts the contaminant plume. Groundwater pumping may be combined with additional treatment technology types and on-site or off-site discharge.

Pumping techniques utilizing extraction wells are reliable, and are proven techniques for the management of groundwater contamination but may not be appropriate for complete aquifer restoration.

3.5.5 Air Stripping

Air stripping is a physical/chemical treatment process in which water and air are brought into contact with each other for the purpose of transferring volatile substances from solution in a liquid to a solution in a gas. The off-gas stream generated during the treatment process may require collection and subsequent treatment.

3.5.6 Carbon Adsorption

Carbon adsorption is a physical/chemical treatment process that binds organic molecules to the surface of the activated carbon particles. The adsorption process involves contacting a waste stream with carbon, usually by flow through a series of packed-bed reactors. Once the micropore surfaces of the carbon are saturated with organics, the carbon is "spent" and must be replaced or regenerated.

The time to reach breakthrough is the most critical operating parameter of this type of treatment system (Rich, 1987).

3.5.7 Neutralization

Neutralization is the interaction of an acid with a base, or vice versa, to yield a final pH of approximately 7.0. This process option is one of the most common types of chemical treatments used by industrial wastewater treatment facilities. Pretreatment of the waste stream may be needed for large amounts of suspended solids and oils and grease. The major limitation of neutralization is that it is subject to the influence of temperature.

3.5.8 Precipitation

Precipitation is a process in which materials in solution are transferred into a solid phase for removal. Removal of heavy metals is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank. Flocculating agents such as alum, ferric chloride, and ferric sulfate may be added to enhance the agglomeration of precipitate particles. The insoluble precipitate is then removed for recovery or disposal using solids separation technologies such as sedimentation or filtration.

3.5.9 Filtration

Filtration is a physical process used to remove suspended solids and biological floc from wastewater. The separation is accomplished by passing water through a physically restrictive medium, resulting in the entrapment of suspended particulate matter. The media typically used for filtration include sand, coal, garnet, and diatomaceous earth. Filtration is generally preceded by chemical precipitation and neutralization.

3.5.10 Flocculation

Flocculation is a process in which chemical coagulants cause colloidal particles to agglomerate into larger particles. Similar to precipitation, the removal of heavy metals is the most common flocculation application in wastewater treatment. Alum, ferric chloride and ferric sulfate are added to the wastewater to agglomerate the flocculated particles.

3.5.11 Sedimentation

Sedimentation is a physical process in which colloidal particles are allowed to settle out of an aqueous waste stream via gravity separation.

3.5.12 In Situ Volatilization (In-Well Aeration)

Air sparging offers a commercially proven technology, while in-well aeration is a somewhat new and innovative technology also referred to as vacuum vapor extraction. Where as air sparging can be thought of as in situ air stripping, in-well aeration can be thought of as in-well air stripping. Air sparging incorporates the injection of air into the water saturated zone for the purpose of removing organic contaminants via volatilization. Once volatilized, the sparged contaminants are generally collected. Soil vapor extraction may be used to collect the volatilized contaminants and convey them to an off-gas treatment system. The process of in-well aeration involves injecting air that is not intended to enter the aquifer into a well (although the air may enter the aquifer in a dissolved form). The resulting in-well airlift pump effect causes water to flow into the well from the deeper screened portion of the well and out of the well from the shallower screened portion (Hinchee, 1994). Volatiles are stripped from the groundwater within the well, rise to the top of the well with the injection air, and are collected and treated at an above ground treatment facility. Under the air sparging or in-well aeration systems, groundwater is treated without being extracted out of the ground. In addition to treating contaminants via volatilization, both technologies may provide enhanced bioremediation within the aquifer and vadose zone.

The depth to groundwater contamination appears to be one limiting factor for the air sparging system. Therefore, since groundwater contamination is roughly 40 to 60 feet bgs, in-well aeration appears to be better suited for alternative development at Site 86.

3.5.13 Monitored Natural Attenuation

The remedial actions associated with monitored natural attenuation include the groundwater monitoring and groundwater modeling to demonstrate the remedial success of the natural attenuation processes. Factors that influence these natural processes include: water content in soil, soil porosity/permeability, clay content, adsorption, soil density, pH, oxidation/reduction potential, temperature, wind, evaporation, precipitation, microbial community, chemical composition and concentration, soil management, and availability of nutrients. Under this response action, many of these natural attenuation parameters would be monitored in addition to monitoring the TCL VOCs within the groundwater.

3.5.14 On-Site Storm Drain Discharge

It appears that treated groundwater from Site 86 can be discharged on site directly into the existing storm drain system. The capacity of the storm drain system, as well as any required discharge permits, must be considered if it is to be used as a discharge location.

3.6 References

Hinchee, 1994. Air Sparging for Site Remediation. Lewis Publishers, Columbus, Ohio.

Rich, Gerald and Kenneth Cherry. 1987. Hazardous Waste Treatment Technologies. Third Printing. Pudvan Publishing Company, Northbrook, Illinois.

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

SECTION 3.0 TABLES

TABLE 3-1

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Access Restrictions	Deed Restrictions
			Fencing
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Capping	Clay/Soil Cap
			Asphalt/Concrete Cap
			Soil Cover
			Multilayered Cap
		Vertical Barriers	Grout Curtain
			Slurry Wall
			Sheet Piling
			Rock Grouting
		Horizontal Barriers	Grout Injection
			Block Displacement
		Extraction	Extraction Wells
			Extraction/Injection Wells
			Hydrofracturing
		Subsurface Drains	Interceptor Trenches
	Treatment Actions	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powdered Activated Carbon Treatment • Trickling Filter • Rotating Biological Contactor
			Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			Chemical Dechlorination
			Ultraviolet (UV) Oxidation
			Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation

TABLE 3-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater (Continued)	Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Chemical Reduction
			Reverse Osmosis
			Ion Exchange
			Electrolysis
			Electrodialysis
			Electrochemical Ion Generation
			Distillation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
			Oil/Water Separation
		Thermal Treatment	Liquid Injection Incineration
			Molten Glass
			Plasma Arc Torch
			Pyrolysis
			Wet Air Oxidation
			Supercritical Oxidation
		Engineered Wetland Treatment	Constructed Wetlands
		Off-site Treatment	RCRA Facility
			Site 82 Treatment System
			Sewage Treatment Plant
		In Situ Treatment	Biodegradation
			In Situ Volatilization (Air Sparging, In-Well Aeration)
			Dual Phase Extraction
			Passive Treatment Wall
			Monitored Natural Attenuation
	Discharge Actions	On-site Discharge	Storm Drains
			Reinjection ● Injection Wells ● Infiltration Galleries
		Off-site Discharge	Sewage Treatment Plant

TABLE 3-2

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No Action - Contaminated groundwater remains as is.	Potentially applicable; required by the NCP.	Retained
Institutional Controls	Monitoring	Groundwater Monitoring	Ongoing monitoring of existing and/or newly installed wells.	Potentially applicable.	Retained
	Access Restrictions	Deed Restrictions	Limit the future use of land including placement of wells.	Deed restrictions are not applicable to military installation not on closure list.	Eliminated
		Fencing	Limit access by installing a fence around contamination area.	A fence alone will not prevent contaminant migration and will interfere with existing structures and roads.	Eliminated
	Aquifer Use Restrictions	Restrictions in Base Master Plan	Prohibit use of the contaminated aquifer as a potable water source.	Potentially applicable.	Retained
Containment/Collection Actions	Capping	Clay/Soil Cap Asphalt/Concrete Cap Soil Cover Multilayered Cap	Capping material placed over areas of contamination.	This process option would not be feasible due to the close proximity of existing structures and roads.	Eliminated
	Vertical Barriers	Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes to contain contamination.	Because there is no apparent confining layer at Site 86, this process option would be impractical.	Eliminated
		Slurry Wall	Trench around areas of contamination. The trench is filled with a soil bentonite slurry to limit migration of contaminants.	Because there is no apparent confining layer at Site 86, this process option would be impractical.	Eliminated
		Sheet Piling	Interlocking sheet pilings installed via drop hammer around areas of contamination.	Because there is no apparent confining layer at Site 86, this process option would be impractical.	Eliminated
		Rock Grouting	Specialty operation for sealing fractures, fissures, solution cavities, or other voids in rock to control flow of groundwater.	The depth to bedrock limits practicality.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Containment/Collection Actions (Continued)	Horizontal Barriers	Grout Injection	Pressure injection of grout to form a bottom seal across a site at a specific depth.	Technique is in the experimental stage. Grout injection alone will not prevent contaminant migration.	Eliminated
		Block Displacement	Continued pumping of grout into specially notched holes causing displacement of a block of contaminated earth.	Technique is in the experimental stage.	Eliminated
	Extraction	Extraction Wells	Series of wells used to extract contaminated groundwater. Well screen must be placed within the identified plume for maximum contaminant collection.	Potentially applicable.	Retained
		Extraction/Injection Wells	Injection wells inject uncontaminated groundwater to enhance collection of contaminated groundwater via the extraction wells. Injection wells can also inject material into an aquifer to remediate groundwater.	Based on the relatively low permeability of soil at the site, injected liquid may mound in the subsurface formations rather than flowing though.	Eliminated
		Hydrofracturing	Pressurized water is injected to create fractures in the formation, thus improving permeability can be used to enhance pump and treat systems.	The fractures may open new passageways through which contaminants can spread.	Eliminated
	Subsurface Drains	Interceptor Trenches	Perforated pipe installed in trenches backfilled with porous media to collect contaminated groundwater. Generally limited to shallow depths.	Depth to contamination eliminates trench feasibility.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powdered Activated Carbon Treatment • Trickling Filter • Rotating Biological Contactor	Degradation of organics using microorganisms in an aerobic environment.	Not highly effective for halogenated VOCs such as TCE.	Eliminated
		Anaerobic	Degradation of organics using microorganisms in an anaerobic environment.	Potentially applicable to halogenated VOCs such as TCE.	Retained
	Physical/Chemical Treatment	Air Stripping	Mixing large volumes of air with water in a packed column to promote transfer of VOCs to air. Effective for VOCs and some SVOCs.	Potentially applicable to VOCs.	Retained
		Steam Stripping	Mixing large volumes of steam with water to promote transfer of VOCs to air.	Not as effective or economical as air stripping.	Eliminated
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing air or water through carbon column. Effective for wide range of organics.	Potentially applicable to VOCs.	Retained
		Chemical Dechlorination	Process which uses specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them to form other less harmful compounds. Effective for PCBs, chlorinated hydrocarbons and dioxins.	Groundwater may require extensive dewatering prior to the application of this technology. Not highly effective for COCs.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Ultraviolet (UV) Oxidation	UV radiation is used to destroy organic contaminants as water flows into a treatment tank; an ozone destruction unit treats off-gases from treatment tank.	Potentially applicable to VOCs.	Retained
		Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation	Addition of an oxidizing agent to raise the oxidation state of a substance. Effective for organics (primarily phenols, pesticides, and sulfur containing wastes), and some metals (primarily iron and manganese).	Not applicable to VOCs.	Eliminated
		Chemical Reduction	Addition of a reducing agent to lower the oxidation state of a substance to reduce toxicity/solubility. Effective for chromium, mercury and lead.	Not applicable to VOCs.	Eliminated
		Reverse Osmosis	Using high pressure to force water through a RO membrane leaving contaminants behind. Effective for dissolved solids (organic and inorganic).	Not applicable as dissolved solids are not anticipated to be primary treatment concern.	Eliminated
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Effective for inorganics, but not iron and manganese.	Not applicable to TCE, and inorganics are not primary treatment concerns.	Eliminated
		Electrolysis	Metal ions are removed when an electric current drives contaminated water through ion exchangers in membrane form. Effective for recoverable metals or cyanide.	Not applicable to VOCs.	Eliminated
		Electrodialysis	Metal ions are removed when an electric current drives contaminated water through ion exchangers in membrane form.	Not applicable to VOCs.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Electrochemical Ion Generation	Electrical currents are used to put ferrous and hydroxyl ions into solution for subsequent removal via precipitation. Effective for metals removal.	Not applicable to VOCs.	Eliminated
		Distillation	Contaminated water is heated so it evaporates leaving contaminants behind. The water vapor is then cooled resulting in condensate of purified water. Highly energy intensive.	Because it is highly energy intensive, this method is not effective for treating groundwater with relatively low contaminant concentrations.	Eliminated
		Neutralization	Addition of an acid or base to a waste in order to adjust its pH. Applicable to acidic or basic waste streams.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Precipitation	Materials in solution are transferred into a solid phase for removal. Effective for suspended solids and metals.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Filtration	Removal of suspended solids from solution by forcing the liquid through a porous medium. Effective for suspended solids and inorganics.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Flocculation	Small, unsettleable particles suspended in a liquid medium are made to agglomerate into large particles by the addition of flocculating agents. Effective for suspended solids and inorganics.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation. Effective for suspended solids.	Potentially applicable as pretreatment for a VOC removal technology.	Retained

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Oil/Water Separation	Materials in solution are transferred into a separate phase for removal. Applicable to petroleum hydrocarbons.	Not applicable to VOCs.	Eliminated
	Thermal Treatment	Liquid Injection Incineration	Combustion of waste at high temperatures. Effective for pumpable organic wastes.	Incineration is expensive when there are relatively low contaminant concentrations in groundwater; such as the VOCs at Site 86.	Eliminated
		Molten Glass	Advanced incineration; waste contacts hot molten salt to undergo catalytic destruction. Effective for hazardous liquids, low ash, high chlorine wastes.	Incineration is expensive when there are relatively low contaminant concentrations.	Eliminated
		Plasma Arc Torch	Advanced incineration; pyrolyzing wastes into combustible gases in contact with a gas which has been energized to its plasma state by an electrical discharge. Effective for liquid organic waste.	Incineration is expensive when there are relatively low contaminant concentrations in groundwater.	Eliminated
		Pyrolysis	Advanced incineration; thermal conversion of organic material into solid, liquid, and gaseous components; takes place in an oxygen-deficient atmosphere. Effective for organics and inorganics.	Pyrolysis is expensive when there are relatively low contaminant concentrations in groundwater.	Eliminated
		Wet Air Oxidation	Advanced incineration; aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures. Effective for organics with high COD, high strength wastes, and for oxidizable inorganics.	Incineration is expensive when there are relatively low contaminant concentrations in groundwater.	Eliminated
		Supercritical Oxidation	An enhanced wet-air oxidation process with reaction conditions in supercritical range of water.	Incineration is expensive when there are relatively low contaminant concentrations in groundwater.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Engineered Wetland Treatment	Constructed Wetlands	An engineered complex of plants, substrates, water, and microbial populations. Contaminants are removed via plant uptake, biodegradation (organics only), precipitation, and sorption processes.	Wetlands are better suited for removal of metals within soils and sediments. The relatively small size and industrialized development of this site would restrict implementation.	Eliminated
	Off-site Treatment	RCRA Facility	Extracted groundwater transported to licensed RCRA facility for treatment and/or disposal.	Potentially applicable.	Retained
		Site 82 Treatment System	Extracted groundwater discharged to treatment system constructed at Site 82.	Potentially applicable.	Retained
		Sewage Treatment Plant	Extracted groundwater discharged to STP for treatment.	Not implementable as Camp Geiger STP will not accept untreated groundwater.	Eliminated
	In Situ Treatment	Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Effective for a wide range of organic compounds.	Potentially applicable to VOCs.	Retained
		In Situ Volatilization (Air Sparging, In-Well Aeration)	"In Situ Air Stripping" (Air Sparging) uses the injection of air under pressure to remove VOCs via volatilization. May be used in conjunction with soil vapor extraction to collect volatilized contaminants in the vadose zone. "In-Well Air Stripping" (In-Well Aeration) is a process of inducing air into a well by applying a vacuum that serves to strip volatiles from groundwater inside the well.	Potentially applicable to VOCs.	Retained

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	In Situ Treatment (Continued)	Dual Phase Extraction	A high vacuum placed in a well removes liquid and gas. Effective for VOCs in low permeability or heterogeneous formations.	The maximum suction lift is approximately 30 ft. bgs, but the plume at Site 86 is located at approximately 40 to 60 ft. bgs.	Eliminated
		Passive Treatment Wall	A permeable wall is installed across the flow path of a contaminant plume, treating the plume as it passively moves through the wall.	Potentially applicable to VOCs; however, the size and industrialized nature of the site limits practicality/ implementation.	Eliminated
		Monitored Natural Attenuation	Natural subsurface processes - such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials - are allowed to reduce contaminant concentrations to acceptable levels.	Potentially applicable to VOCs.	Retained
Discharge Actions	On-site Discharge	Storm Drains	Treated water discharged to existing storm sewer.	Potentially applicable.	Retained
		Reinjection • Injection Wells • Infiltration Galleries	Treated water reinjection into the site aquifer via use of shallow infiltration galleries (trenches) or via injection wells.	Injected liquid may mound in the subsurface formation and cause damage to existing adjacent structures. Preliminary 2-D models showed no significant treatment life benefit.	Eliminated
	Off-site Discharge	Sewage Treatment Plant	Treated water discharged STP.	Potentially applicable.	Retained

TABLE 3-3

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND
PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Extraction	Extraction Wells
	Treatment Actions	Biological Treatment	Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Carbon Adsorption
			Ultraviolet (UV) Oxidation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		Off-site Treatment	RCRA Facility
			Site 82 Treatment System
		In Situ Treatment	Biodegradation
			In situ Volatilization (Air Sparging, In-Well Aeration)
			Monitored Natural Attenuation
	Discharge Actions	On-Site Discharge	Storm Drains
		Off-Site Discharge	Sewage Treatment Plant

TABLE 3-4

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
No Action	No Action	Not Applicable	• Effectiveness depends on contaminant concentrations, risks associated with the contaminants, and the effects of natural attenuation	• Easily implemented	• No cost	Retained as per the requirements of the NCP
Institutional Controls	Monitoring	Groundwater Monitoring	• Will effectively detect contaminant increases so that exposure can be avoided	• Easily implemented	• Low capital • Low O & M	Retained because of its effectiveness, implementability, and low cost
	Aquifer Use Restrictions	Restrictions in Base Master Plan	• Effective at preventing future exposure to contaminated groundwater • Effectiveness dependent on continued future implementation	• Easily implemented • A Notice of Inactive Hazardous Substances and Waste Disposal Sites would require NC DENR concurrence.	• Negligible cost	Retained because of its effectiveness, implementability, and negligible cost
Containment/ Collection Actions	Extraction	Extraction Wells	• Conventional, widely demonstrated technology • Effective for collecting and/or containing a contaminated groundwater plume • Inorganics may precipitate and clog well screens; this necessitates frequent maintenance and equipment replacement	• Easily implemented • Potential exposures during implementation • Equipment readily available	• Moderate capital • Low O&M	Retained because it is a conventional technology that can be implemented with relative ease
Treatment Actions	Biological Treatment	Anaerobic	• Technology is still under development so it is not widely demonstrated • Elevated VOCs may be toxic to organisms • Very slow process • Effectiveness is susceptible to variation in waste stream characteristics and environmental parameters	• Mobile units available • Methane gas is produced and must be utilized or disposed • Low contaminant concentrations may make operation difficult	• Moderate capital • Moderate O & M	Eliminated because it has not been widely demonstrated

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	Physical/Chemical Treatment	Air Stripping	• Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • Commercially proven technology • Contaminant transfer rather than destruction technology	• Off-gas and/or tower scale treatment may be required • May require air emissions permit • Mobile units available • Equipment and vendors readily available	• Low to moderate capital • Low to moderate O & M	Air stripping will be retained because of its effectiveness for contaminants that are highly volatile with low water solubility, its commercial availability, performance record, and its relatively low cost
		Carbon Adsorption	• Commercially proven and widely used technology • Contaminant transfer rather than destruction technology • Can be used as a polishing step following air stripping • Inorganics can foul the system	• Spent carbon must be regenerated or properly disposed • Pretreatment may be required to reduce or remove suspended solids, oil and grease and unstable chemical compounds • Equipment readily available and conventional	• Moderate capital • Moderate to high O & M (dependent on loading rates and carbon life)	Retained because of its commercial availability and performance record, and its relatively moderate cost
		UV Oxidation	• Commercially proven technology • Inorganics such as chromium, iron, and manganese may limit effectiveness • High turbidity limits the transmission of UV light • Contaminant destruction rather than transfer technology • VOCs may be volatilized rather than destroyed and off-gas treatment will be required	• Energy-intensive • Handling and storage of oxidizers requires special safety precautions • System is easily automated • System is easy to transport and set up	• Moderate to high capital • High O & M	Eliminated because it is energy-intensive, requires special safety precautions, and has a relatively high cost
		Neutralization	• Can be used in a treatment train for pH adjustment	• Widely used and well-demonstrated • Simple and readily available equipment/materials	• Low capital • Low to moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Precipitation	• Effective, reliable, permanent, and conventional technology • Typically used for removal of heavy metals • Followed by solids-separation method • Generates sludge which can be voluminous, difficult to dewater, and may require treatment	• Equipment is basic and easily designed • Compact, single units can be delivered to the site	• Low capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Filtration	• Conventional, proven method of removing suspended solids from wastewater • Does not remove contaminants other than suspended solids • Generates a sludge which requires proper handling	• Equipment is relatively simple to install and no chemicals are required • Package units available	• Low capital • Low O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Flocculation	• Conventional, proven technology • Applicable to aqueous waste stream where particles must be agglomerated into larger more settleable particles prior to other types of treatment • Performance depends on the variability of the composition of the waste being treated	• Equipment is readily available and easy to operate • Can be easily integrated into more complex treatment systems	• Low capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation: Effectiveness	Evaluation: Implementability	Evaluation: Relative Cost	Evaluation Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Sedimentation	• Conventional, proven technology • Effective for removing suspended solids and precipitated materials from wastewater • Performance depends on density and particle size of the solids, effective charge on the suspended particles, types of chemicals used in pretreatment, surface loading, upflow rate, and rejection time • Feasible for large volumes of water to be treated	• Effluent streams include the effluent water, scum, and settled solids	• Moderate capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
	Off-Site Treatment	RCRA Facility	• Preliminary testing is required to determine effectiveness and reliability	• Readily implementable if facility will accept waste • May be difficult to gain facility acceptance of waste • Distance to nearest facility may make implementation more difficult • Transporting contaminated groundwater via trucking may be challenging due to industrialized site location and adjacent property uses	• Moderate capital • Moderate O&M	Eliminated because distance to the nearest facility is excessive and implementation via trucking may be difficult
		Site 82 Treatment System	• Effective and reliable for VOC removal	• System has capacity to accept the groundwater • Transportation via pipeline may not be feasible due to distance to the system • Transportation via trucking is feasible • Distance to Site 82 treatment system may make implementation via trucking more difficult	• Moderate to high capital • Moderate O&M	Eliminated because implementation may be difficult and costs are relatively high

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	In Situ Treatment	Biodegradation	• Technology is still under development so it is not widely demonstrated • Very slow process • Injection of substrate and nutrients into groundwater may mobilize contaminants • Most effective for a site that has both soil and groundwater contamination, rather than just groundwater contamination	• Injection of substrate and nutrients into groundwater may require a permit • Equipment readily available	• Moderate to high capital • Low to moderate O&M	Eliminated because technology is still under development and costs are generally high
		In Situ Volatilization (Air Sparging, In-Well Aeration)	• Groundwater does not need to be lifted above ground surface in order to be treated • Contaminant transfer rather than destruction technologies • More effective for larger vadose zones • Fouling of the system may occur by oxidized constituents in the groundwater • Commercially proven technology for generally more shallow groundwater contamination (Air Sparging)	• Secondary treatment of off-gas may be required • May require air emissions permit • Implementable to relatively deep depths (in-well aeration)	• Moderate to high capital • Low to moderate O&M	In-Well Aeration is retained for FS alternative development over air sparging primarily due to depth of contaminated groundwater at Site 86
			• Contamination of the vadose zone may occur as contaminated groundwater passes through it (Air Sparging) • Soil vapor extraction may be necessary to collect volatilized contaminants (Air Sparging) • Limited commercial track record (In-Well Aeration) • Provides a closed loop system for air circulation; volatiles are less likely to escape because they will be collected within the aeration wells (In-Well Aeration)			

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	In Situ Treatment (Continued)	Monitored Natural Attenuation	• Effective for fuel related contaminants • Effective only in the presence of a long-term monitoring program	• Requires a treatability study • Requires a long-term monitoring program • No other O&M requirements besides long-term monitoring	• Negligible to low capital • Low O&M	Retained because it is effective for the contaminants of concern
	On-Site Discharge	Storm Drains	• Effective and reliable discharge method via existing storm drainage system	• Based on the low pumping rates expected, the existing storm drainage system should have the capacity to handle discharge from a treatment system	• Low capital • Low O&M	Retained due to implementability and low cost
	Off-Site Discharge	Sewage Treatment Plant	• Effective and reliable discharge method via sanitary sewer system • Extensive pretreatment of waste required	• Discharge permit may need modified • Pipeline modifications and flow diversions may be required • Capacity of the Camp Geiger STP may not be able to accept the flow	• Moderate capital • Low O&M	Eliminated because of limited pipeline system size/capacity

TABLE 3-5

FINAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Extraction	Extraction Wells
	Treatment Actions	Physical/Chemical Treatment	Air Stripping
			Carbon Adsorption
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		In Situ Treatment	In Situ Volatilization (In-Well Aeration)
			Monitored Natural Attenuation
	Discharge Actions	On-Site Discharge	Storm Drains

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

In this section, remedial action technologies and process options chosen for Site 86 will be combined to form RAAs. Following the development of these RAAs (Section 4.1), each RAA may be evaluated against the short-term and long-term aspects of three criteria: effectiveness, implementability, and cost (Section 4.2). The RAAs with the most favorable evaluation will be retained for further consideration during the detailed analysis performed in Section 5.0. The screening evaluation in this section of the FS is optional, and will only be conducted if too many RAAs are initially developed.

4.1 Development of Remedial Action Alternatives

RAAs were developed by combining the general response actions, remedial action technologies, and process options that are listed on Table 3-5. Five RAAs were developed: no action, institutional controls, monitored natural attenuation, extraction and on-site treatment, and in-situ volatilization (in-well aeration). The following subsections describe these RAAs.

4.1.1 RAA 1: No Action

Under the no action RAA, no physical remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater at Site 86. The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs that provide a greater level of response.

Although this RAA does not involve physical remediation, passive remediation of the groundwater is expected to occur via processes associated with the natural attenuation of contaminants. Under the no action alternative, however, no means are considered or incorporated to monitor or confirm the natural remedial process. Therefore, overall protection of human health and the environment will be unknown.

Since contaminants will remain at Site 86 under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years. The 5-year reviews will include a site visit to evaluate if there is evidence of further contaminant migration, and a review of current applicable regulations. If there is a change at the site, appropriate actions will be evaluated.

4.1.2 RAA 2: Institutional Controls

Under RAA 2, no physical remedial actions will be performed at Site 86; however, passive remediation of groundwater is expected to occur through natural attenuation. In addition, this RAA includes institutional controls will include a groundwater monitoring program, coupled with aquifer use and residential development restrictions.

The purpose of the groundwater monitoring program is to track contaminant migration over time and to evaluate any fluctuations in COC levels. Under the program, groundwater samples will be collected semiannually at the monitoring wells identified on Figure 4-1. As shown, nine wells will be monitored under this program: six existing intermediate wells (86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW, 86-GW25IW), and three existing deep wells (86-GW15DW, 86-GW16DW, 86-GW19DW). The intermediate and deep wells will monitor COC levels in the surficial and the Castle Hayne aquifers. Samples collected from these wells will be analyzed for TCL VOCs. Additional wells may be added to the program, if necessary. Semiannual monitoring reports will be prepared to record the analytical results obtained from the groundwater monitoring program. For costing purposes, it is assumed that the monitoring wells will require replacement every 5 years.

In addition to groundwater water monitoring, the Base Master Plan will be modified to include aquifer use and future residential development restrictions. These restrictions and institutional controls as described in Section 3.5.3 will prohibit future use of the aquifer within 1,500 feet of the estimated groundwater plume at Site 86. They will also assure that the site will not be developed for residential use. To ensure that the restrictions are upheld, annual certification that the restrictions in the Base Master Plan have remained unchanged and deed recordation of a "Notice" will be required. Upon signature of the ROD, the plat associated with the "Notice" shall be submitted for NC DENR concurrence. The RCRA Permit Modification which imposes site restrictions will be modified. Finally, in the event that the property is transferred to another party, MCB, Camp Lejeune shall state that the site has been used as a hazardous waste disposal site, record the site restrictions, and outline the responsibilities of the Navy and the transferee in the form of restrictive covenants at the Onslow County register of deeds' office prior to the transfer.

Similar to RAA 1, remediation of groundwater is expected to occur via the process associated with natural attenuation. Although the monitoring under RAA 2 is designed to track the constituent concentrations, this RAA does not incorporate the sampling requirements necessary to confirm the progress of the natural attenuation processes at Site 86.

Since contaminants will remain at Site 86 under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years until the RLs are met. The 5-year reviews will include a site visit and a review of the monitoring reports and current regulations.

4.1.3 RAA 3: Monitored Natural Attenuation

Under RAA 3, no physical remedial actions will be conducted to reduce the toxicity, mobility, or volume of the groundwater contaminants at Site 86. However, the remedial actions associated with natural attenuation are expected to occur. These actions will be monitored under RAA 3. Natural attenuation processes include in situ naturally occurring biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization/destruction of the VOCs in groundwater are expected in the form of natural attenuation. The term "natural attenuation" refers to the "naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in these media" (Wiedemeier, 1996).

Biodegradation may occur as an aerobic, anaerobic, or cometabolic process. Aerobic processes involve oxidation-reduction reactions in which oxygen is the electron receptor. Anaerobic processes involve iron-reducing, denitrifying, and sulfate-reducing reactions. Cometabolic processes involve carbon dioxide-reducing reactions and result in the accumulation of methane as a final product. The natural biodegradation of fuel-related compounds (e.g., benzene) is more fully documented than the natural biodegradation of chlorinated solvent contaminants (e.g., TCE, 1,2-DCE, vinyl chloride). Technical literature, however, indicates that both fuel and chlorinated solvent contamination can undergo natural attenuation through one or a combination of the biodegradation processes mentioned. At Site 86, the following evidence suggests that natural attenuation processes are successfully degrading the chlorinated solvent contamination in the surficial aquifer:

- PCE and TCE have been detected within the monitoring wells located at Site 86. In addition, the TCE daughter product (1,2-DCE) has also been detected.
- The fact that the ASTs were removed in 1992, coupled with the knowledge that PCE and TCE were not detected in soil samples collected from this area, suggests that the source has been removed while the residual constituents appear to have migrated to the groundwater.
- The locations and concentrations of the TCE and 1,2-DCE detections are positioned as to suggest that the daughter product is a result of the PCE and TCE degredation. Based upon this information, the monitored natural attenuation alternative appears to be a justifiable remedial option for the chlorinated solvent contamination detected at Site 86.

The primary component of RAA 3 is an extensive monitoring program focused on evaluating the effectiveness of natural attenuation. The monitoring program for RAA 3 will include groundwater sampling (and soil sampling when appropriate). The groundwater samples will be submitted for laboratory analyses of the following parameters: TCL VOCs, total organic carbon (TOC), nitrate, sulfate, methane, ethane, ethene, and chloride. Additionally, field analyses will be conducted on groundwater samples to determine the levels of oxygen, iron II, alkalinity, oxidation-reduction potential (ORP), pH, temperature, conductivity, major cations, and hydrogen. Both the laboratory and field parameters are identified and described in more detail on Table 4-1. Collection and review of the analytical results will indicate the type of bioremediation that is occurring, (i.e., aerobic, iron-reducing, denitrifying, sulfate-reducing, or methanogenic). Over time, the results will be used to predict the kind and amount of contaminant reduction that has occurred, as well as, the amount of contaminant reduction that is expected to occur in the future.

Figure 4-2 identifies the following 15 monitoring wells that will monitor both TCL VOCs and the aforementioned natural attenuation parameters: 86-GW08IW, 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW23IW, 86-GW25IW, 86-GW28IW, 86-GW29IW, 86-GW30IW, 86-GW31IW, 86-GW32IW, 86-GW15DW, 86-GW19DW, 86-GW31DW, and UST well AS428-GW06. Monitoring wells 86-GW31DW and 86-GW32IW will be new wells installed under this RAA. The intermediate and deep wells will monitor concentrations in both the surficial and Castle Hayne aquifers. Should additional sampling locations be necessary, they will be added to the monitoring program. If the analytical results indicate that the groundwater quality has improved, the monitoring program may be refined to include fewer sampling locations or less frequent sampling events. Monitoring, in some capacity, will continue until groundwater standards for the organic COCs have been met. However, for cost estimating purposes, 5 years of quarterly sampling, followed by 25 years of semiannual sampling will be assumed. In turn, the cost estimate for RAA 3 incorporates the reduction of analytical costs by 50 percent starting in the sixth year of the program. Semiannual monitoring reports will be prepared to record the analytical results obtained from the groundwater monitoring program. For costing purposes, it is assumed that the monitoring wells to be sampled will require placement every 5 years.

In an effort to provide additional evidence that natural attenuation is occurring, RAA 3 incorporates the option of performing a groundwater contaminant fate and transport model. The cost estimate accounts for annual modeling, as new results become available.

RAA 3 also includes the aquifer use and future residential development restrictions that are included under RAA 2. The aquifer use restrictions will prohibit future use of the surficial and Castle Hayne aquifers within 1,500 feet of the estimated groundwater plume at Site 86. These restrictions eliminate the aquifers from any use. As defined under RAA 2, these restrictions will be implemented through modifications to the Base Master Plan, annual certification, deed recordation, and restrictive covenants (in the event of property transfer).

Until RLs are met, the NCP [40 CFR 300.430(f)(4)] requires that the lead agency review the effects of this alternative at least once every five years. The 5-year reviews will include a site visit and a review of the monitoring reports and current regulations.

4.1.4 RAA 4: Extraction and On-Site Treatment

Extraction and on-site treatment, selected as RAA 4, is a conventional extraction and treatment alternative in which groundwater will be collected by extraction wells, and transported to an on-site treatment plant for VOC removal. Once treated, the groundwater will then be discharged to the existing storm drains.

Since pump tests have never been conducted at Site 86, there is no conclusive way to determine the pumping rate and capture radius for an extraction well at the site. In lieu of a pump test, the pumping rate and radius of influence were estimated based on slug test data, the site geology, and the site hydrogeology. This information was then used for a USGS two-dimensional groundwater model to best represent site conditions and extraction influence (Appendix B). The pumping rate per extraction well was estimated to be 5 gallons per minute (gpm). Based on this pumping rate, the groundwater model indicated a capture radius of approximately 100 feet. Due to the close proximity of several large buildings, additional concerns regarding aquifer drawdown necessitate a relatively low pumping rate.

All of the above information was used to develop the conceptual system layout and cost estimate for the FS. These estimations are not intended to be used as design parameters. If RAA 4 is selected as the preferred RAA, a pump test should be conducted to more accurately determine the pumping rate and capture radius that can be expected at the site. Data from the pump test will then be utilized to perform more sophisticated groundwater flow and transport models (three-dimensional) to further evaluate the number and placement of extraction wells, as well as any adverse effects pumping may cause to the structural integrity of the neighboring buildings and infrastructure (roads, utilities, etc). The cost associated with a pump test and modeling efforts has been included in the RAA 4 cost estimate.

Figure 4-3 identifies the conceptual system layout that will be used for RAA 4. This conceptual layout is subject to change during the design phase based on new and/or more accurate information that may become available. The conceptual layout was based on information available to date and was adequate for developing the FS cost estimate. Therefore, the conceptual layout is not intended to be the final design layout should this RAA be selected.

As shown on Figure 4-3, three extraction wells will be installed to collect groundwater from the surficial and Castle Hayne aquifers. The extraction wells will be positioned so that their combined zones of influence intercept the maximum concentrations within the contaminant plume. Each extraction well will be screened approximately 40 to 60 feet bgs.

After being extracted, the groundwater will be transported by pipeline to the on-site treatment plant. At the treatment plant, the groundwater will undergo suspended solids and metals removal via neutralization, precipitation, flocculation, sedimentation, and filtration units, and VOC treatment via a low profile air stripper. In addition, carbon adsorption will provide secondary treatment of the VOC emissions from the air stripper and of the treated groundwater. The treatment unit will be designed so that air emissions will comply with the North Carolina Air Pollution Control Regulations. A conceptual process flow diagram for the presented treatment process is shown on Figure 4-4. After receiving treatment, groundwater will be discharged to the existing storm drain system which is expected to have the capacity to accept the estimated 15 gpm discharge. For costing purposes, it is assumed that the groundwater treatment system will operate for 30 years.

In addition to groundwater extraction, treatment, and discharge, RAA 4 incorporates a groundwater monitoring program to measure the effectiveness of this RAA over time. The nine monitoring wells included under this program are those identified under RAA 2. The wells include: 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW, 86-GW25IW, 86-GW15DW, 86-GW16DW, and 86-GW19DW. These well locations are identified on Figure 4-3. Monitoring will be conducted semiannually and samples will be analyzed for TCL VOCs. Additional wells may be added to this monitoring program if necessary. Semiannual monitoring reports will be prepared to record the analytical results obtained from the groundwater monitoring program. For costing purposes, it is assumed that the nine monitoring wells will be replaced every 5 years.

Additionally, aquifer use and future residential development restrictions, described under RAA 2, will be implemented via the Base Master Plan and other requirements as described under RAA 2. The aquifer use restrictions will prohibit future use of the surficial and Castle Hayne aquifers within a 1,500 foot radius of Site 86; while the development restrictions will eliminate the possibility of future residential development.

Until RLs are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years. The 5-year reviews will include a site visit and a review of the monitoring reports and current regulations.

4.1.5 RAA 5: In-Situ Volatilization (In-Well Aeration)

As previously noted within Section 3.5.12, in-well aeration was selected over air sparging to best remediate the groundwater at Site 86. This selection was based on present site specific information (e.g., depth of contaminated groundwater); however, is not intended to eliminate air sparging from future in-situ volatilization consideration.

Currently, an in-well aeration pilot test is being conducted at Site 69, Rifle Range Chemical Dump. Similarly, an air sparging pilot test is being conducted at Site 35, Camp Geiger Fuel Farm. Both of these pilot tests are nearing completion of their original approach. The preliminary results of the Site 69 in-well aeration pilot test will be combined with data collected through July of 1997. A summary report, including recommendations, is anticipated in September 1997. Similarly, the air sparging pilot test at Site 35 will be modified to include horizontal sparging. Construction and operation of the Site 35 pilot test is anticipated through the Spring of 1998. Results and recommendations of the Site 35 pilot test will be documented in the Fall of 1998. Once definitive data becomes available regarding system operations and remedial success, RAA 5 may be modified to better describe the most appropriate in-situ volatilization process for Site 36.

As initially described, in-well aeration is a type of air sparging in which air is injected into a well creating an in-well air-lift pump effect. This pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out of the top of the well. As the groundwater circulates through the well, the injected air stream strips volatiles. (As a result, in-well aeration is often referred to as in-well air stripping.) The volatiles are captured at the top of the well and treated via a carbon adsorption unit. Appendix C contains some technical information that further describes the in-well aeration technology.

Figure 4-5 presents a conceptual layout for the in-well aeration system. This conceptual layout is subject to change during the design phase based on new and/or more accurate information that may become available. The conceptual layout was based on information available to date and will be adequate for developing the FS cost estimate. However, the conceptual layout is not intended to be the final design layout should RAA 5 be selected.

At Site 86, the approximate radius of influence for an aeration well has been estimated to be 65 feet. This estimate, made by a technology vendor, was based on site-specific geologic and hydrogeologic parameters. As shown on Figure 4-5, five aeration wells, with overlapping radii of influence, will be arranged to intercept the area which contains the maximum detected VOC concentrations. This conceptual layout was based on information currently available and was adequate for developing the FS cost estimate. The conceptual layout is not intended to be the final design layout should this RAA be selected.

A typical in-well aeration well and associated treatment processes are depicted on Figure 4-6. As designed, RAA 5 includes a centralized treatment facility where the associated knockout tank(s), vacuum pumps and carbon adsorption units will be located. The aeration system quoted includes the installation of both the air injection and extraction lines, as well as asphalt excavation and repair. The knockout tank(s) will remove any liquids that may have traveled up the well (the amount of knockout liquid is anticipated to be minimal) and the carbon adsorption unit(s) will treat off-gases that were stripped within the well. A field pilot test is recommended to determine the loss of efficiency over time as a result of the expected inorganic precipitation and oxidation, the radius of influence of the wells under various heads of pressure, and the rate of off-gas organic contaminant removal via carbon adsorption.

In addition to the in-well aeration system, RAA 5 incorporates a groundwater monitoring program to measure the effects of this remedial action alternative. Similar to RAAs 2 and 4, nine monitoring wells are included under this program. The locations of the wells are identified on Figure 4-5. Monitoring will be conducted semiannually and samples will be analyzed for TCL VOCs. Additional wells may be added to this monitoring program if necessary. Also, aquifer use and future residential development restrictions will be implemented via the Base Master Plan and institutional controls as described in Section 3.5.3.

Until RLs are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years. The 5-year reviews will include a site visit, and a review of the monitoring reports and current regulations.

4.2 Screening of Alternatives

Typically, this section of the FS presents the initial screening of the potential RAAs. The objective of this screening is to make comparisons between similar alternatives so that only the most promising ones are carried forward for further evaluation (USEPA, 1988). This screening is an optional step in the FS process, and is usually conducted if there are too many RAAs to perform the detailed evaluation on. For Site 86, the decision was made to eliminate this preliminary RAA screening step. Therefore, all of the developed RAAs will undergo the detailed evaluation presented in Section 5.0.

4.3 References

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

Wiedemeier, T.H.; Swanson, M.A.; Montoux, D.E.; Gordon, E.K.; Wilson, J.T.; Wilson, B.H.; Kampbell, D.H.; Hansen, J.E.; Haas, P.; Chapelle, F.H. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Parsons Engineering, Inc., USEPA, AFCEE Technology Transfer Division, and USGS, 1996.

SECTION 4.0 TABLE

TABLE 4-1

NATURAL ATTENUATION PARAMETERS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Soil	Total Organic Carbon (TOC)	SW9060 modified for soil samples	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the aquifer matrix.	Fixed-Base Laboratory
Water	Volatile Organic Compounds (VOCs)	Contract Laboratory Protocol	Method of analysis includes benzene, toluene, ethylene, and xylenes (BTEX) and chlorinated solvents/byproducts, which are the primary target analytes for monitoring natural attenuation.	Fixed-Base Laboratory
Water	Oxygen	Dissolved oxygen meter	Concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Field
Water	Nitrate	IC Method E300	Substrate for microbial respiration if oxygen is depleted.	Fixed-Base Laboratory
Water	Iron (II) (Fe^{2+})	Colorimetric Hach Method #8146	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Field
Water	Sulfate (SO_4^{2-})	IC Method E300	Substrate for anaerobic microbial respiration.	Fixed-Base Laboratory
Water	Methane, ethane, and ethene	Kampbell et al., 1989 or SW3810 Modified	The presence of CH_4 suggests BTEX degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing biological transformation.	Fixed-Base Laboratory

TABLE 4-1 (Continued)

NATURAL ATTENUATION PARAMETERS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	Alkalinity	Hach alkalinity test kit model AL AP MG-L	General water quality parameter used (1) to measure the buffering capacity of groundwater, and (2) as a marker to verify that all site samples are obtained from the same groundwater system.	Field
Water	Oxidation-reduction potential (ORP)	A2580B	The ORP of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the ORP of groundwater may range from more than 800 mV to less than -400 mV.	Field
Water	pH	Field probe with direct reading meter	Aerobic and anaerobic processes are pH-sensitive.	Field
Water	Temperature	Field probe with direct reading meter	Well development.	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Field
Water	Major cations	SW6010	Can be used to evaluate other remedial actions.	Field
Water	Chloride	IC Method E300	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system. Final product of chlorinated solvent reduction.	Fixed-Base Laboratory

TABLE 4-1 (Continued)

NATURAL ATTENUATION PARAMETERS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	TOC	SW9060	Used to classify plume and to determine if cometabolism is possible in the absence of anthropogenic carbon.	Fixed-Base Laboratory
Water	Hydrogen (H_2)	Equilibration with gas in the field. Determined with a reducing gas detector.	Determine terminal electron accepting process. Predicts the possibility for reductive dechlorination.	Field

Reference: Wiedemeier, Todd, et al. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

SECTION 4.0 FIGURES

NOTE: LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs INCLUDING;
86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW,
86-GW25IW, 86GW15DW, 86-GW16DW, AND 86-GW19DW.

303526FS

LEGEND

86-GW01	SHALLOW MONITORING WELL
86-GW04IW	INTERMEDIATE MONITORING WELL
86-GW18DW	DEEP MONITORING WELL
FLOW	DIRECTION OF SURFACE WATER FLOW
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE
	ASPHALT ROAD
	CENTERLINE OF DRAINAGE SWALE
	LIGHTPOLE
	STRUCTURE
	DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE AREA OF CONCERN
	GRAVEL ROAD
	FENCE
	GUY WIRE
	FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991

150 0 75 150
1 inch = 150 ft.

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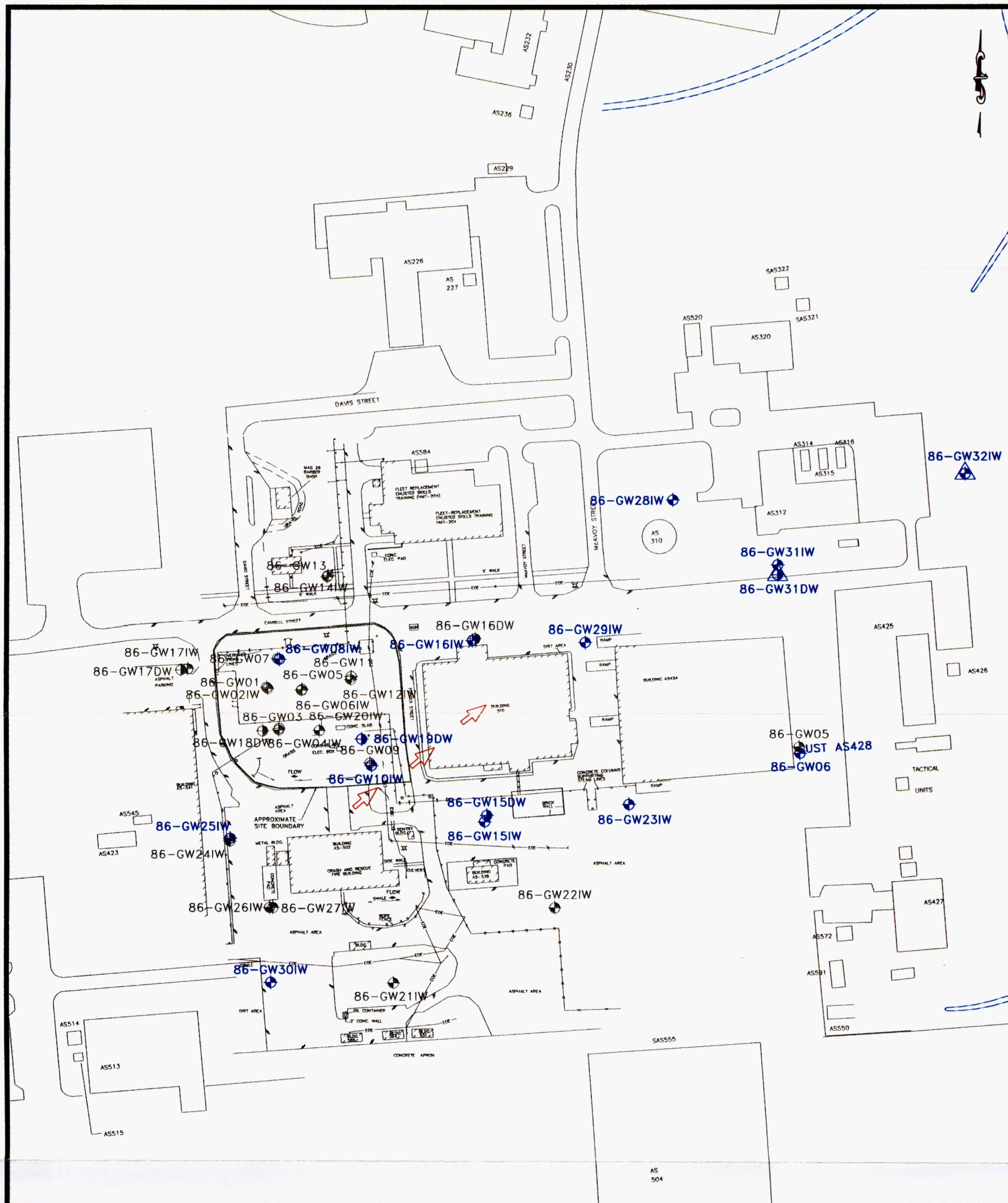
Baker Environmental, Inc.

FIGURE 4-1
RAA No. 2: INSTITUTIONAL CONTROLS
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE

02644CB34



NOTE:
LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs AND THE NATURAL ATTENUATION PARAMETERS, INCLUDING EXISTING WELLS: 86-GW08IW, 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW23IW, 86-GW25IW, 86-GW28IW, 86-GW29IW, 86-GW30IW, 86-GW31IW, 86-GW15DW, 86-GW19DW, AND UST WELL AS428-GW06; AND NEW WELLS 86-GW31DW AND 86-GW32IW.

303527FS

LEGEND

86-GW01	SHALLOW MONITORING WELL
86-GW04IW	INTERMEDIATE MONITORING WELL
86-GW18DW	DEEP MONITORING WELL
FLOW	DIRECTION OF SURFACE WATER FLOW
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE
	ASPHALT ROAD
	CENTERLINE OF DRAINAGE SWALE
	LIGHTPOLE
	STRUCTURE
86-GW32IW	PROPOSED MONITORING WELL
	DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE AREA OF CONCERN
	GRAVEL ROAD
	FENCE
	GUY WIRE
	FIRE HYDRANT

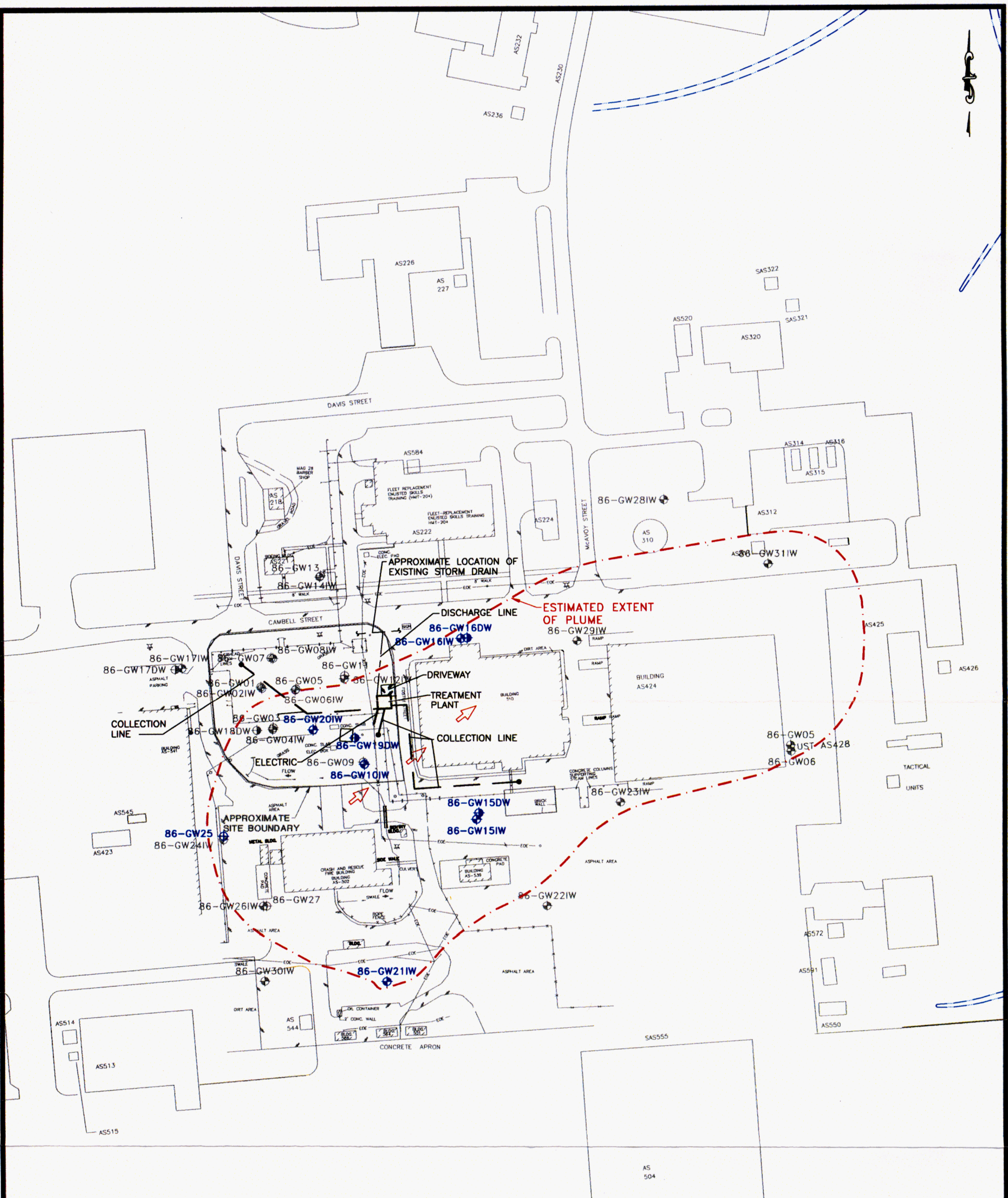
SOURCE: LANTDIV, OCT. 1991

150 0 75 150
1 inch = 150 ft.

Baker
Baker Environmental, Inc.

FIGURE 4-2
RAA 3: MONITORED NATURAL ATTENUATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE



NOTE: LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs INCLUDING; 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW, 86-GW25IW, 86GW15DW, 86-GW16DW, AND 86-GW19DW.

303529FS

LEGEND

86-GW01	SHALLOW MONITORING WELL
86-GW04IW	INTERMEDIATE MONITORING WELL
86-GW18DW	DEEP MONITORING WELL
FLOW	DIRECTION OF SURFACE WATER FLOW
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE
	ASPHALT ROAD
	CENTERLINE OF DRAINAGE SWALE
	LIGHTPOLE
	STRUCTURE
	DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE AREA OF CONCERN
	EXTRACTION WELL
	GRAVEL ROAD
	FENCE
	GUY WIRE
	FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991

150 0 75 150
1 inch = 150 ft.

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FIGURE 4-3
RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE

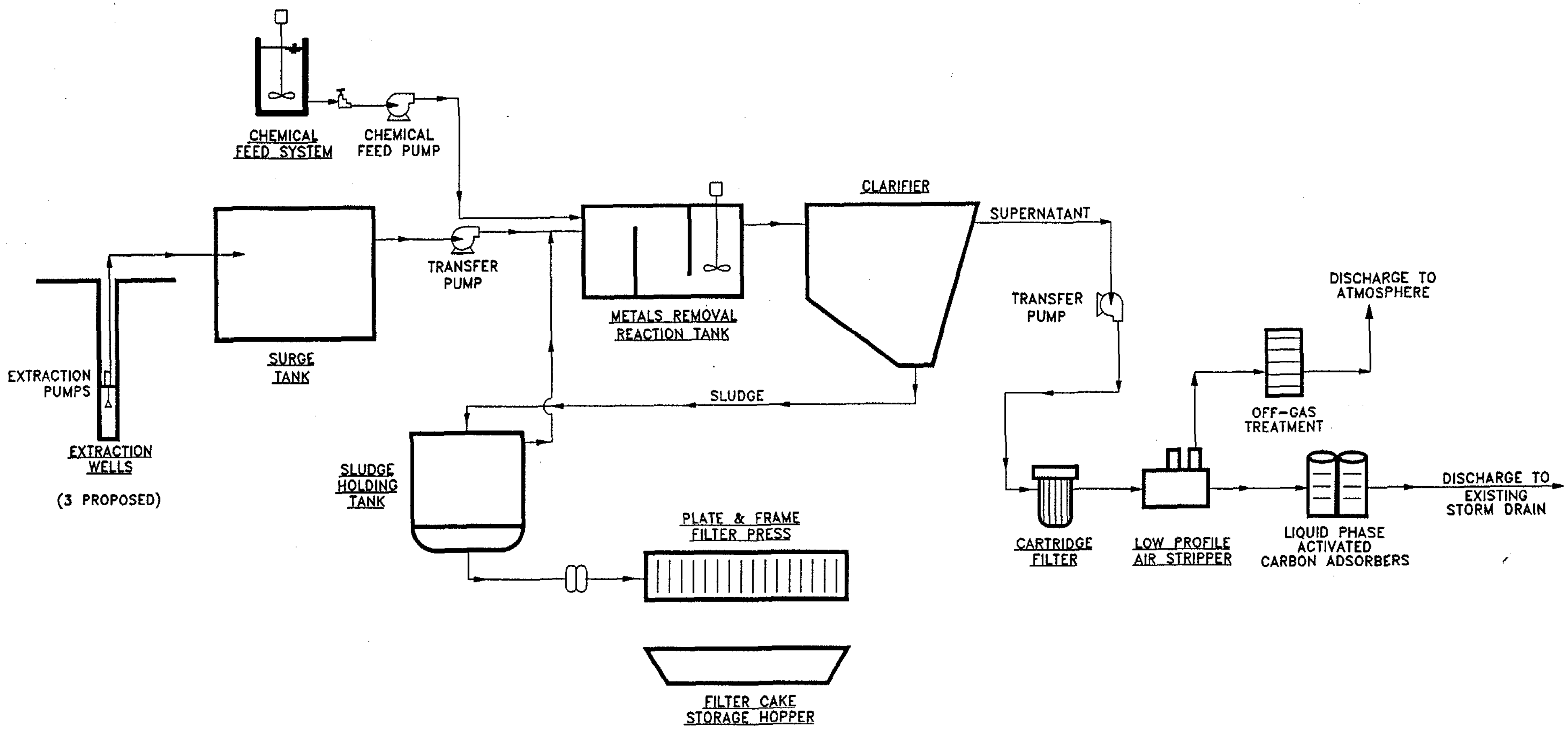

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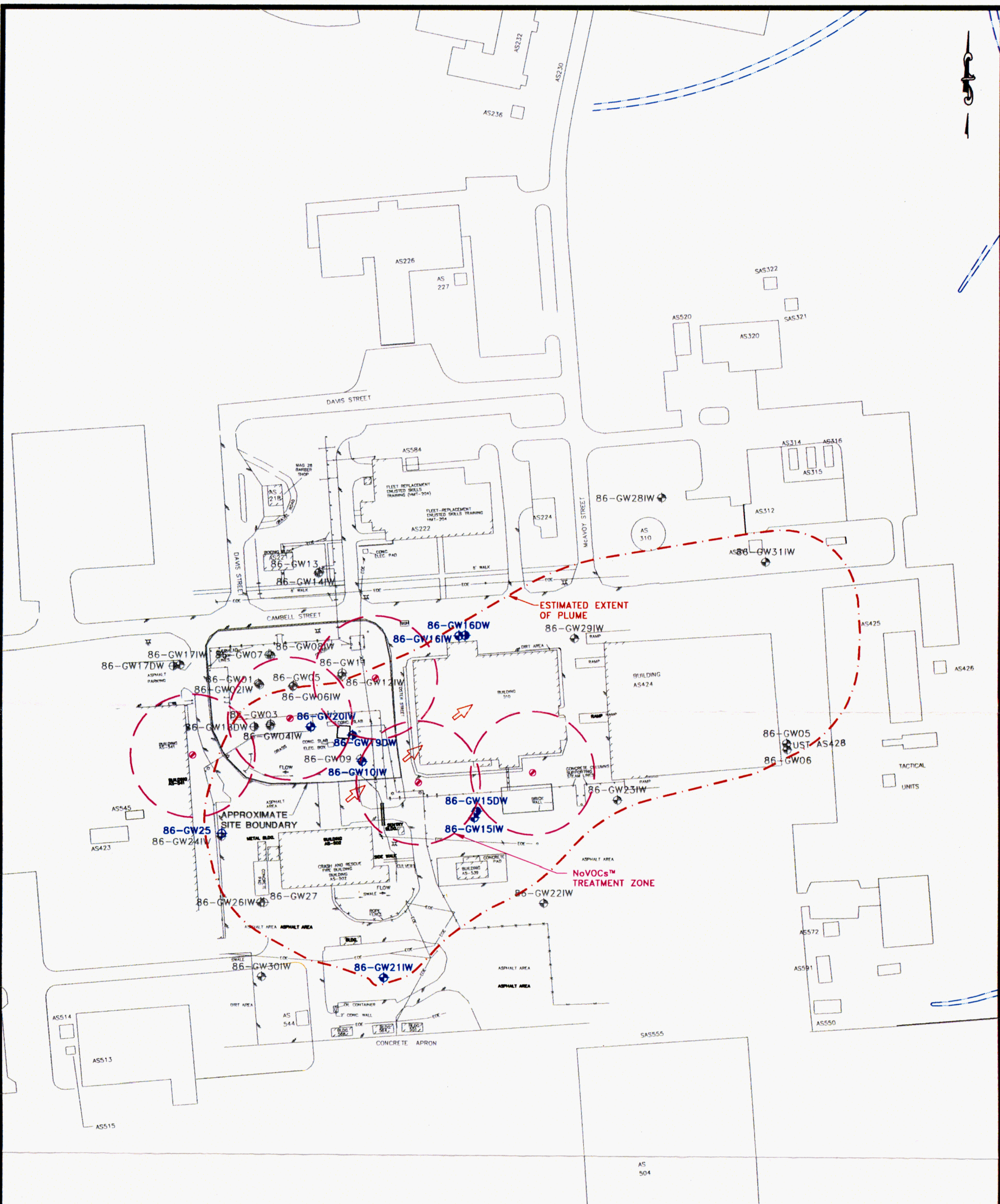
FIGURE 4-4
RAA 4: EXTRACTION AND ON-SITE TREATMENT PROCESS FLOW DIAGRAM
SITE 86, TANK AREA AS-419-AS421 AT MCAS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

303027FS



NOTE: LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs INCLUDING; 86-GW10IW, 86-GW15IW, 86-GW16IW, 86-GW20IW, 86-GW21IW, 86-GW25IW, 86GW15DW, 86-GW16DW, AND 86-GW19DW.

303528FS

LEGEND

86-GW01	SHALLOW MONITORING WELL
86-GW04IW	INTERMEDIATE MONITORING WELL
86-GW18DW	DEEP MONITORING WELL
FLOW	DIRECTION OF SURFACE WATER FLOW
EOE	OVERHEAD ELECTRIC LINE & UTILITY POLE
	ASPHALT ROAD
	CENTERLINE OF DRAINAGE SWALE
	LIGHTPOLE
	STRUCTURE
	DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE AREA OF CONCERN
	AERATION WELL
	GRAVEL ROAD
	FENCE
	GUY WIRE
	FIRE HYDRANT

SOURCE: LANTDIV, OCT. 1991

150 0 75 150

1 inch = 150 ft.

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FIGURE 4-5
RAA No. 5: IN-WELL AERATION
SITE 86, TANK AREA AS419-AS421 AT MCAS
FEASIBILITY STUDY, CTO-0303

MARINE CORPS AIR STATION, NEW RIVER
CAMP LEJEUNE

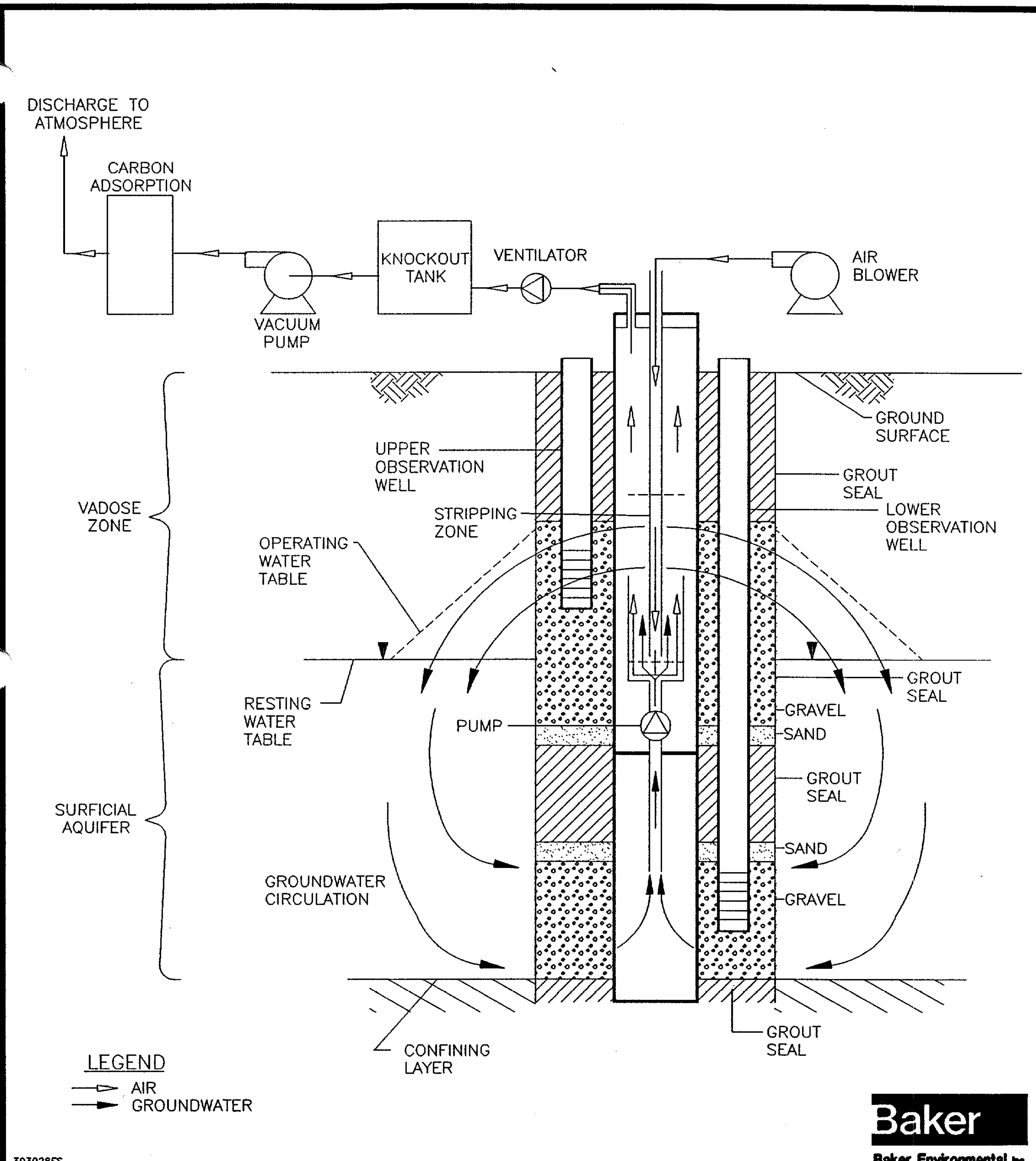

FIGURE 4-6
RAA 4: IN-WELL AERATION
TYPICAL WELL DETAIL AND PROCESS FLOW DIAGRAM
SITE 86, TANK AREA AS-419-AS421 AT MCAS

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

5.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section presents the detailed analysis of the RAAs that were developed in Section 4.0. Section 5.1 presents an overview of evaluation criteria that will be used in the detailed analysis. Sections 5.2 and 5.3 present the two parts of the detailed analysis: the individual analyses of RAAs, and the comparative analysis of RAAs, respectively.

This detailed analysis has been conducted to provide sufficient information to adequately compare the alternatives, select an appropriate remedy for the site, and demonstrate satisfaction of the CERCLA remedy selection requirements in the Record of Decision (ROD). The extent to which alternatives are assessed during the detailed analysis is influenced by the available data, the number and types of alternatives being analyzed, and the degree to which alternatives were previously analyzed during their development and screening (USEPA, 1988). (The initial screening of alternatives was not necessary for Site 86.)

The detailed analysis of alternatives was conducted in accordance with the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA, 1988) and the NCP, including the February 1990 revisions. In conformance with the NCP, seven of the following nine criteria were used for the detailed analysis:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance (not evaluated at this time)
- Community acceptance (not evaluated at this time)

State acceptance and community acceptance will be evaluated in the ROD by addressing comments received after the Technical Review Committee (TRC) has reviewed the FS and Proposed Remedial Action Plan (PRAP). The TRC includes participants from the NC DENR, USEPA Region IV, and the public.

5.1 Overview of Evaluation Criteria

The following paragraphs describe the evaluation criteria that are used in the detailed analysis.

Overall Protection of Human Health and the Environment: Overall protection of human health and the environment is the primary criteria that a remedial action must meet. A remedy is considered protective if it adequately eliminates, reduces, or controls all current and potential site risks posed through each exposure pathway at the site. A site where hazardous substances remain without engineering or institutional controls allows for unlimited exposure for human and environmental receptors. Adequate engineering controls, institutional controls, or some combination of the two, can be implemented to control exposure and thereby ensure reliable protection over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts on human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs): Compliance with ARARs is one of the statutory requirements for remedy selection. Alternatives are developed and refined throughout the FS process to ensure that they will meet all ARARs or that there is a sound rationale for waiving an ARAR. During the detailed analysis, the alternatives will be analyzed based on the Federal and State chemical-specific ARARs, the action-specific ARARs, and the location-specific ARARs that were presented in Section 2.0 of this FS.

Long-Term Effectiveness and Permanence: This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the environment in the distant future, as well as the near future. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford, the analysis will focus on the residual risks present at the site after the completion of the remedial action. The analysis will also include consideration of the following:

- Degree of threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering and institutional controls) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

Reduction of Toxicity, Mobility, or Volume Through Treatment: This criterion addresses the statutory preference for remedies that employ treatment as a principal element. The criterion ensures that the relative performance of the various treatment alternatives in reducing the toxicity, mobility, or volume will be assessed. Specifically, the analysis will examine the magnitude, significance, and irreversibility of reductions.

Short-Term Effectiveness: This criterion examines the short-term impacts associated with implementing the alternative. Implementation may impact the neighboring community, workers, or the surrounding environment. Short-term effectiveness also includes potential threats to human health and the environment associated with the excavation, treatment, and transportation of hazardous substances, the potential cross-media impacts of the remedy, and the time required to achieve protection of human health and the environment.

Implementability: Implementability considerations include the technical and administrative feasibility of the alternatives, as well as the availability of goods and services (including treatment, storage, or disposal capacity) associated with the alternative. Implementability considerations often affect the timing of remedial actions (e.g., limitations on the season in which the remedy can be implemented, the number and complexity of material handling steps, and the need to secure technical services). On-site activities must comply with the substantive portions of applicable permitting regulations.

Cost: Cost includes all capital costs and O&M costs incurred over the life of the project. The focus during the detailed analysis is on the present worth of these costs. Costs are used to select the most cost-effective alternative that will achieve the remedial action objectives.

In accordance with USEPA guidance (USEPA, 1988), the cost estimates will have an accuracy of -30 to +50 percent. The exact accuracy of each cost estimate depends upon the assumptions made and the availability of costing information. In order to calculate the net present worth (NPW), the operating costs for each year of operation in the future are converted to current dollars. These costs assume a five percent discount factor and a zero percent inflation rate. The converted annual costs are totaled and then added to the capital costs to find the NPW of the alternative.

Unless noted otherwise, it has been assumed that groundwater monitoring will be conducted for thirty years. This assumption has been made for costing purposes only.

State Acceptance: This criterion, which is an ongoing concern throughout the remedial process, reflects the statutory requirement to provide for substantial and meaningful State involvement. State comments will be addressed during the development of the FS, the PRAP, and the ROD, as appropriate. The State will confirm its acceptance of the remedy with a concurrence letter to be included in the Final ROD.

Community Acceptance: This criterion addresses the community's comments on the remedial alternatives under consideration, where "community" is broadly defined to include all interested parties. These comments are taken into account throughout the FS process. However, formal public comment will not be received until after the public comment period for the PRAP is held, so only preliminary assessment of community acceptance can be conducted during the development of the FS.

5.2 Individual Analysis of Alternatives

The following subsections present the detailed analysis of RAAs on an individual basis. This individual analysis includes a brief description of each RAA and an assessment of how well the RAA performs against seven of the nine previously introduced evaluation criteria. Table 5-1 summarizes the individual, detailed analysis of alternatives.

5.2.1 RAA 1: No Action

Description

Under the no action alternative, groundwater at Site 86 will remain as is. No physical remedial actions will be implemented.

Assessment

***Overall Protection of Human Health and the Environment*:** Under RAA 1, no remedial actions will be implemented. Even though natural attenuation processes may occur, overall protection to human health and the environment will be unknown since monitoring will not take place.

Compliance With ARARs: Under RAA 1, no active effort will be made to reduce contaminant levels to below Federal and State chemical-specific ARARs. Over an indefinite period of time, however, passive remediation, in the form of natural attenuation processes, may reduce VOC levels to below ARARs. However, under the no action RAA, acknowledgement and/or confirmation of the passive remediation will not be completed.

No location-specific ARARs apply to this no action alternative.

However, RAA 1 does not comply with the action-specific ARAR for North Carolina groundwater, corrective actions (15A NCAC 2L.0106-.0113).

Long-Term Effectiveness and Permanence: Residual risk will remain at the site under the no action alternative as humans could potentially come in contact with the contaminated groundwater. However, it is highly unlikely that this scenario will occur because the on-site groundwater is not used as a potable source, and due to the industrialized setting of Site 86 it is unlikely that the area would be developed for future residents. In addition, the VOC contaminants did not generate unacceptable risks. Thus, the residual risks associated with leaving contaminants untreated at the site will be minimal.

Under the no action alternative, any long-term or permanent effect on contaminant levels will depend on the effectiveness of the natural attenuation processes. The extent to which natural attenuation may reduce contaminant levels, and the time it will take, are difficult to predict.

Because the contaminants will remain on site at levels exceeding ARARs, RAA 1 will require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. The 5-year reviews will include a site visit to evaluate if there is evidence of contaminant migration and a review of applicable regulations. If there is a change at the site, appropriate actions will be evaluated.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The no action alternative does not provide physical treatment processes for toxicity, mobility, or volume reduction of contaminated groundwater. Passive treatment processes (i.e., natural attenuation) may eventually provide toxicity and volume reduction of the contaminated plume. However, the extent to which natural attenuation may reduce contaminant toxicity and volume is difficult to predict. Because there is no treatment process, there will be no treatment residuals. Although this RAA may satisfy the statutory preference for treatment, no means are provided to measure the effects. Thus, the statutory preference for treatment cannot be justified.

Short-Term Effectiveness: There are no remedial action activities associated with RAA 1. As a result, short-term potential risks to the community will not be increased, there will be no risks to workers, and there will be no additional environmental impacts. The exact time until the action is complete (i.e., the time required for natural attenuation to remediate the aquifer) is unknown.

Implementability: The no action alternative is implementable since no additional construction or operation activities will be conducted. In terms of administrative feasibility, RAA 1 should not require additional coordination with other agencies, although a waiver of the State ARARs may be required since VOC levels exceeding these ARARs will be left on site indefinitely. The availability of services, materials, and/or technologies is not applicable to this alternative.

Additional remedial actions could easily be implemented under RAA 1.

Cost: There are no capital costs or O&M costs associated with this alternative. Therefore, the NPW is $0.

5.2.2 RAA 2: Institutional Controls

Description

RAA 2 differs from the no action alternative by including the following institutional controls: a groundwater water monitoring program, and aquifer use and future residential development restrictions. Under the proposed monitoring program, samples will be collected semiannually from nine wells (six existing intermediate wells, and three existing deep wells). All of the samples will be analyzed for TCL VOCs. Aquifer use restrictions, implemented via the Base Master Plan, will prohibit future use of the surficial and Castle Hayne aquifers within 1,500 feet of the estimated plume at Site 86 and institutional controls as described in Section 3.5.3.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 2, institutional controls will reduce potential human health risks associated with exposure to groundwater. The monitoring program will indicate any increase in and/or migration of VOC concentrations so that appropriate action can be taken. Thus, the monitoring program mitigates the potential for human exposure. Due to the industrial nature of the site, an ecologically diverse population is not expected here. Therefore, Site 86 should not be impacted adversely by site-related contaminants. Aquifer use and future residential development restrictions also mitigate the potential for human exposure by prohibiting the use of the surficial aquifer, providing recordation of the Notice at the Onslow County courthouse, and eliminating the potential for future residents. RAA 2 does not include extensive measures to monitor the effectiveness of the natural attenuation processes.

Compliance With ARARs: Under RAA 2, no physical effort will be made to reduce contaminant levels to below Federal and State chemical-specific ARARs. Over an indefinite period of time, however, passive remediation in the form of natural attenuation processes, may reduce contaminant levels to or below their associated ARARs. The monitoring program under this RAA will be able to determine if/when the ARARs are met.

No location-specific ARARs apply to this alternative.

However, the RAA will not comply with the action-specific ARAR 15A NCAC 2L.0113 without a variance.

Long-Term Effectiveness and Permanence: The magnitude of residual risk associated with leaving contaminated groundwater untreated at the site is minimal. The VOC contaminants did not generate unacceptable risks, even for the highly unlikely scenario: future residential development. Nevertheless, RAA 2 will reduce any residual risk that remains at the site because the aquifer use restrictions will restrict groundwater from being used for any purpose (except for monitoring under the remedial action). The future and the monitoring program will detect improvement or deterioration in groundwater quality. In addition, the restrictions on the future development of Site 86 eliminates the risks to future residents. Therefore, RAA 2 will provide long-term effectiveness for mitigating potential exposure.

Because RAA 2 does not include active groundwater remediation, any long-term or permanent effect on contaminant levels will depend on the effectiveness of natural attenuation. However, the extent to which natural attenuation may reduce contaminant levels, and the exact time it will take, are difficult to predict.

RAA 2 is based on adequate and reliable institutional controls that will help to manage the untreated groundwater contamination remaining in the aquifer. The proposed monitoring program will be an adequate and reliable control for assessing the effectiveness of the RAA, and aquifer use restrictions will be adequate and reliable controls for preventing future use of the aquifers as a potable water source. Aquifer use and future residential development restrictions, however, must be enforced over time to ensure their adequacy and reliability.

Because contamination will remain on site, RAA 2 will require 5-year reviews to ensure that adequate protection of human health and the environment is maintained.

***Reduction of Toxicity, Mobility, or Volume Through Treatment*:** RAA 2 does not provide a physical treatment process for toxicity, mobility, or volume reduction of the contaminated groundwater. Over an indefinite period of time, passive treatment processes (i.e., natural attenuation) may eventually provide toxicity and volume reduction. The extent to which this will occur, however, is difficult to predict. Because there is no physical treatment process, there will be no treatment residuals. RAA 2 may satisfy the statutory preference for treatment through natural attenuation; however, this RAA offers no means of monitoring its progress. Therefore, the statutory preference for treatment cannot be justified.

***Short-Term Effectiveness*:** Under RAA 2, there will be no increase of short-term potential risks to the community or workers. RAA 2 will not create any additional environmental impacts. The exact time required for the action (i.e., natural attenuation) to be complete is unknown; however, groundwater monitoring was assumed for 30 years for cost estimating purposes.

***Implementability*:** RAA 2 is technically implementable since groundwater sampling, and aquifer and land use restrictions have been easily implemented in the past. In addition, groundwater sampling has residential development proven to be a reliable, easy to maintain technology.

If groundwater quality appears to be deteriorating over time, additional remedial actions could easily be implemented along with RAA 2.

In terms of administrative feasibility, semiannual reports must be submitted to document sampling procedures. This alternative should not require additional coordination with other agencies. All required services, materials, and/or technologies should be readily available.

Cost: Table 5-2 presents a cost estimate for RAA 2. As shown, there are no estimated capital costs associated with RAA 2. O&M costs of approximately $26,000 annually are projected for sampling nine wells semiannually for 30 years. Assuming a discount rate of 5 percent, the estimated NPW of this alternative is $400,000.

5.2.3 RAA 3: Monitored Natural Attenuation

<u>Description</u>

Under RAA 3, no physical remedial actions will be implemented to reduce the contamination detected at Site 86. Instead, treatment via natural attenuation processes will be relied upon to reduce contaminant levels. The main component of RAA 3 is an expanded groundwater monitoring program. Groundwater samples will be analyzed for TCL VOCs and natural attenuation parameters. These parameters will indicate the type of natural biodegradation that is occurring in the aquifer, and the amount of contaminant reduction that has occurred over time and that can be expected. Monitoring has been estimated for a period of 30 years, but will continue until the groundwater ARARs for the organic COCs are met.

RAA 3 includes aquifer use and future residential development restrictions to prohibit future use of the surficial and Castle Hayne aquifers within 1,500 foot of the estimated plume at Site 86. To further support the occurrence of natural attenuation, RAA 3 includes the optional components of annual contaminant fate and transport modeling.

<u>*Assessment*</u>

Overall Protection of Human Health and the Environment: Under RAA 3, contaminants in the surficial and Castle Hayne aquifers will remain. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- Results of the human health and ecological risk assessments indicate that the chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- Current technical literature indicates that fuel-related compounds and chlorinated solvents are capable of naturally attenuating, provided the appropriate conditions are present at the site. The contamination at Site 86 appears to be naturally attenuating as TCE and the daughter product of TCE degradation (1,2-DCE) have been detected. Thus, the groundwater contamination at Site 86 is expected to naturally attenuate over time.

Based on this information, additional physical groundwater treatment is not necessary to provide a justifiable solution for the surficial aquifer. RAA 3 ensures the protection of human health and the environment through natural attenuation, monitoring, aquifer use restrictions, and optional fate and transport modeling. Thus, RAA 3 will mitigate the potential for direct exposure and provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 3, no physical effort will be made to enhance or reduce contaminant levels to below chemical-specific ARARs. Natural attenuation processes; however, are expected to eventually achieve these ARARs. Thus, RAA 3 has the potential to remediate the groundwater over an extended period of time. No location-specific ARARs apply to this alternative. However, this RAA would have to comply with the action-specific groundwater corrective action ARAR 15A NCAC 2L.0106(l).

Long-Term Effectiveness and Permanence: Allowing the groundwater to naturally attenuate is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant at present and in the future; 2) the chlorinated solvent contamination appears to be naturally attenuating. Through monitoring and aquifer use and land restrictions, RAA 3 provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the surficial and Castle Hayne aquifers, and eliminating the possibility of future residential development.

As a result, RAA 3 will ensure the safety of potential receptors over time and will provide long-term effectiveness and permanence.

Under RAA 3, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 3 does not provide additional physical treatment processes; however, some reduction in toxicity, mobility, and volume through natural attenuation processes is anticipated and will be monitored. Thus, RAA 3 satisfies the statutory preference for treatment.

Short-Term Effectiveness**:** Under RAA 3, the only activities that may increase risks to the community and to workers include monitoring well installation and periodic groundwater sampling. However, proper material handling procedures and personal protective equipment should sufficiently protect the community and workers against these risks. RAA 3 will not create any additional environmental impacts. The time required for the action to be complete is unknown, but 30 years of monitoring was assumed for cost estimating purposes.

Implementability**:** RAA 3 is a technically implementable alternative since groundwater monitoring, and aquifer use restrictions have been easily implemented in the past.

If groundwater quality appears to be deteriorating over time, additional remedial actions could easily be implemented under RAA 3.

In terms of administrative feasibility, this alternative will not require additional coordination with other agencies. However, semiannual reports must be submitted to document sampling procedures. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 3 is $83,000. The projected annual O&M costs are approximately $93,000 for quarterly sampling in years 1-5, and $57,000 for semiannual sampling in years 6-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is approximately $960,000. Table 5-3 presents the cost estimate for RAA 3.

5.2.4 RAA 4: Extraction and On-Site Treatment

Description

Prior to initiating the system design, a site-specific pump test and three-dimensional groundwater flow/transport models will be performed. For alternative development; however, RAA 4 involves the installation of three extraction wells that will intercept the contaminated plume as it moves in the direction of groundwater flow. Each extraction well will have a capacity of 5 gpm. Once the groundwater is extracted, it will undergo VOC treatment at an on-site treatment plant. The treatment will consist of suspended solids/metals removal, air stripping, and vapor phase carbon adsorption of the VOC air stripper emissions. Likewise, the groundwater will receive secondary treatment via liquid phase carbon adsorption prior to being discharged. In addition, RAA 4 includes a groundwater monitoring program, and aquifer use and residential land development restrictions as institutional controls.

Assessment

Overall Protection of Human Health and the Environment: Because RAA 4 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health. The monitoring program will indicate any increase in and/or migration of VOC concentrations so that appropriate action(s) can be taken. Thus, the monitoring program mitigates the potential for human exposure. Aquifer use restrictions also mitigate the potential for human exposure by prohibiting the use of the surficial aquifer. Similarly, the land development restrictions will eliminate the possibility of future residential development. The extraction/treatment system mitigates human health risks by decreasing the VOC concentrations. Under RAA 4, there will be a reduction in potential ecological risks via active treatment and institutional controls. Overall; however, site related contamination should not adversely impact ecological receptors.

Compliance With ARARs: Under RAA 4, the groundwater quality will be improved through the use of an active remediation system, groundwater extraction and treatment. Over time, contaminant concentrations may meet Federal and State chemical-specific groundwater ARARs via active remediation. RAA 4 can be designed to meet the chemical-specific ARARs regulating air and water discharge.

In addition, RAA 4 can be designed to meet the location-specific and action-specific ARARs that apply.

Long-Term Effectiveness and Permanence: The magnitude of residual risk associated with leaving contaminated groundwater at the site is minimal, because the VOC contaminants did not generate unacceptable risks. Nevertheless, RAA 4 will reduce any residual risk that remains at the site because: (1) the aquifer use restriction will prohibit groundwater from being used as a potable water source in the future, (2) the monitoring program will detect any improvement or deterioration in groundwater quality, and (3) groundwater extraction and treatment will reduce VOC levels. As a result, RAA 4 is expected to provide long-term effectiveness and performance.
Groundwater extraction/treatment methods are both adequate and reliable controls. However, technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Also, contaminants may continue to leach from solid particles below the vadose zone. Due to this partitioning of contaminants, extraction technologies may not be reliable for completely remediating the aquifer. The potential for inorganic precipitation to clog well screens also limits the reliability of extraction wells. As with most remediation equipment, there is a potential for replacement and/or repairs. However, all of the treatment technologies associated with RAA 4 (for example, air stripping) have demonstrated their adequacy and reliability.

RAA 4 includes adequate and reliable institutional controls that will help monitor contaminant levels remaining in the aquifer. The proposed monitoring program will be an adequate and reliable control for assessing the effectiveness of the RAA; while the aquifer and development restrictions will be adequate and reliable controls for preventing future use of the aquifer or residential development at Site 86. Aquifer and residential development restrictions (as described in Section 3.5.3), however, must be enforced over time to ensure their adequacy and reliability.

RAA 4 will require 5-year reviews by the lead agency.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 4 include neutralization, precipitation, flocculation, sedimentation, and filtration for suspended solids/metals removal, air stripping for VOC removal, and secondary treatment of VOC emissions from the air stripper and the treated groundwater (vapor and liquid phase carbon adsorption, respectively). These treatment processes will be effective for pretreating inorganics and primarily treating VOCs in the groundwater.

The treatment processes associated with RAA 4 will reduce the toxicity and volume of contaminated groundwater; while the pumping effect of the extraction wells will reduce the mobility of the contaminated groundwater plume. In addition, the treatment processes are expected to have irreversible effects.

Residuals remaining after treatment may include metals sludge, spent carbon, and treated groundwater. The sludge is expected to be nonhazardous, but will require proper disposal. The spent carbon will require regeneration or proper disposal. Once treated, groundwater is expected to be within acceptable discharge limits; therefore, discharge to the existing storm drain system is anticipated.

RAA 4 satisfies the statutory preference for treatment.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community. In addition, workers may require protection during the installation and operation of the extraction/treatment system. In terms of environmental impacts, RAA 4 may cause localized aquifer drawdown during groundwater extraction. However, due to the concern for the structural integrity of the adjacent buildings and underground utilities, the pumping rate per extraction well was specifically designed to minimize aquifer drawdown. Therefore, the overall environmental impact due to extraction is considered negligible, but will be reassessed/confirmed during future three-dimensional modeling.

With respect to the time required to complete the remedial action, the groundwater extraction/treatment system is expected to be operated for many years prior to achieving complete groundwater restoration. The exact amount of time is unknown; however, 30 years of operation have been assumed for costing purposes.

Implementability: RAA 4 is technically implementable; however, the adjacent industrialized setting of Site 86 may hinder system construction and/or operation. All of the associated technologies/process options are conventional and have proven to be implementable. Major system technical difficulties are not anticipated.

There is a potential for high dissolved metals to precipitate out of solution and clog the well screens. This would require frequent well maintenance and replacement. There is also a potential for equipment replacement at the treatment plant. Releases of VOCs from the air stripper may also be a concern; however, measures to control atmospheric emissions have been included.

Another disadvantage for system operation is the fact that groundwater must be lifted above ground surface. This requires more power, more extensive treatment processes, and the need to discharge the treated groundwater.

If the monitoring program indicates that groundwater quality is deteriorating, additional remedial actions could easily be implemented under RAA 4.

In terms of administrative feasibility, RAA 4 requires extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of air and water discharge permits will have to be met. However, all required services, materials, and/or technologies should be readily available.

Cost: Table 5-4 presents a cost estimate for RAA 4. As shown, the estimated capital cost is approximately $532,000, including the $27,000 costs associated with the pump test and three-dimensional groundwater modeling. O&M costs of approximately $59,000 are projected for treatment plant O&M and groundwater/surface water monitoring for 30 years. Assuming a discount rate of 5 percent, the NPW of this alternative is approximately $1,440,000.

5.2.5 RAA 5: In-Well Aeration

Description

As presented, RAA 5 involves the installation of five in-well aeration wells. The aeratiion wells will be installed with overlapping capture radii so that they intercept the contaminated groundwater. The VOCs collected by each aeration well will receive carbon adsorption treatment. A field pilot test will be conducted to assure design efficiency. In addition, RAA 5 includes a groundwater monitoring program, and aquifer and residential development restrictions as institutional controls (the same as under RAAs 2 and 4).

Assessment

***Overall Protection of Human Health and the Environment*:** Because RAA 5 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health. The monitoring program will indicate any increase in and/or migration of VOC or inorganics concentrations so that appropriate action can be taken. Thus, the monitoring program mitigates the potential for human exposure. Aquifer use restrictions also mitigate the potential for human exposure by prohibiting the use of the surficial aquifer; and land development restrictions will prohibit the possibility of future residential development. In-well aeration mitigates human health risks by decreasing VOC concentrations. Under RAA 5, there will be a reduction in potential ecological risks; even though present concentrations of VOCs did not generate unacceptable risks, and the overall ecological risks were considered negligible.

***Compliance With ARARs*:** Under RAA 5, the groundwater quality will be improved through the use of an active remediation system, in-well aeration. Over time, the contaminated groundwater may meet Federal and State ARARs as a result of active remediation. RAA 5 can be designed to meet chemical-specific ARARs regulating air and water discharge.

In addition, RAA 5 can be designed to meet the applicable location-specific and action-specific ARARs.

***Long-Term Effectiveness and Permanence*:** RAA 5 will reduce the magnitude of residual risks for the following reasons: (1) the aquifer use restrictions will restrict groundwater from being used for any purpose (except for monitoring), (2) the monitoring program will detect any improvement or deterioration in groundwater quality, and (3) the in-well aeration system will reduce VOC levels. Because in-well aeration is a new and innovative technology that has not been well demonstrated, its adequacy and reliability is uncertain. Based on its limited performance record, in-well aeration appears to be an adequate and reliable alternative to remediate the contaminated groundwater at Site 86. The surficial aquifer's hydraulic conductivity at Site 86, estimated by conducting slug tests (1.22×10^{-3} cm/sec), will allow injected air to flow freely through the saturated zone of the surficial aquifer. Since the target contaminant groups for in-well aeration include halogenated volatiles, the technology will be effective for treating TCE, PCE, DCE, and benzene.

Like most groundwater remediation methods, in-well aeration will only be adequate and reliable to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Also, contaminants may continue to leach from solid particles below the vadose zone. As a result, remediation methods may not be completely reliable for extracting contaminants from the groundwater. In addition, because of the groundwater circulation effect it creates, in-well aeration may spread contaminants from the groundwater to non-contaminated soil in the vadose zone. This may limit its long-term effectiveness.

The potential for inorganics precipitation to clog the well screens may also limit the long-term effectiveness of in-well aeration. As with most remediation equipment, there is the potential for equipment repair and/or replacement.

Under RAA 5, the proposed monitoring program and periodic O&M system checks will be adequate and reliable controls for determining the effectiveness of the alternative. If they are enforced over time, aquifer use restrictions will be adequate and reliable controls for preventing future human exposure to the groundwater.

RAA 5 will require 5-year reviews by the lead agency until the RLs are met.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 5 include in-well air stripping and off-gas carbon adsorption for VOC removal. These treatment processes are effective for treating halogenated VOCs. Thus, the in-well aeration system will reduce the toxicity and volume of contaminated groundwater as it passes through the wells. The treatment effects are expected to be irreversible; however, may reintroduce contaminants into the vadose zone.

Residuals remaining after treatment will include the small amount of condensed vapor left in the knockout tanks and the spent carbon. The liquid within the knockout tanks is expected to be non-hazardous; however, the spent carbon will contain adsorbed contaminants and will require disposal or regeneration.

RAA 5 satisfies the statutory preference for treatment.

Short-Term Effectiveness: Adequate site controls may be necessary to minimize dust production during the aeration well installation. Therefore, the short-term risk to the community, associated with installation, will be minimal. In addition, workers may require protection during the installation and operation of the system. However, the system will create no additional environmental impacts.

The time required to complete the remedial action cannot be estimated; however, thirty years of operation have been assumed for cost estimating purposes.

Implementability: Although in-well aeration has been commercially applied, it is still a relatively new technology. Regardless, RAA 5 appears to be technically implementable at Site 86 based on current knowledge of the site. Two important advantages of this system are the fact that groundwater does not have to be lifted above the ground surface in order to be treated and the depths to which aeration wells can be constructed. However, in any in situ system where oxygen is injected, metals precipitation and oxidation may occur. At high enough levels, these metals can clog the well screens requiring frequent maintenance and equipment replacement.

If the monitoring program indicates that groundwater quality is deteriorating, additional remedial actions could easily be implemented under RAA 5.

In terms of administrative feasibility, RAA 5 will require extensive coordination with the Base Public Works/Planning Department. Although there are a limited number of in-well aeration vendors, the required services, materials, and/or technologies should be readily available.

Cost: Table 5-5 presents a cost estimate for RAA 5. As shown, the estimated capital cost is \$865,000. O&M costs of \$52,000 are projected for 30 years of system operation and groundwater monitoring. Assuming a discount rate of 5 percent, the NPW of this alternative is approximately \$1,660,000.

5.3 <u>Comparative Analysis</u>

This section presents a comparative analysis of the five groundwater alternatives presented for Site 86. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA. Thus, seven of the nine previously introduced criteria used for the detailed analysis will be the basis for the following comparative analysis.

5.3.1 Overall Protection of Human Health and the Environment

RAA 1, the no action alternative, does not reduce potential risks to human health nor the environment. On the other hand, RAAs 2, 3, 4, and 5 do reduce potential human health risks because they all involve institutional controls which prevent future exposure to the groundwater. RAA 3 provides additional protection through monitoring and modeling of natural remedial processes. RAAs 4 and 5 involve active remediation systems (extraction and on-site treatment or in-well aeration) which provide additional protection to human health. However, the additional protection that RAAs 4 and 5 provide may not be necessary considering the minimal human health risks associated with contaminated groundwater.

Human health risk values generated for groundwater at Site 86 only exceeded acceptable limits under the future residential exposure scenario. However, due to the industrial nature of Site 86, it is highly unlikely that future residential development will ever occur. As a result, the future residential exposure scenario and all risk values generated there under are overly conservative and unrealistic. Risk values generated under the current land use scenario at Site 86 were within acceptable limits. Thus, the potential risks associated with VOC contamination appear minimal.

Considering the minimal human health risks associated with contaminated groundwater encountered under unlikely scenarios, monitored natural attenuation (RAA 3) should be adequate for protecting human health and the environment. Active treatment via groundwater extraction and treatment (RAA 4) or in-well aeration (RAA 5) will be unnecessary to provide adequate human health or environmental protection. No action, however, provides no protection; while RAA 2 (institutional controls) allows the natural attenuation to continue virtually unnoticed. Therefore, RAAs 1 and 2 may be inferior to the other three alternatives, while RAAs 4 and 5 may overcompensate for the minor risks that exist at the site.

RAAs 4 and 5 provide for risk reduction to ecological receptors. However, due to the site's industrial setting, adverse impacts to ecological receptors are not expected. In addition, VOCs (including TCE, PCE, DCE, and benzene) did not generate unacceptable risks. As a result, VOCs in the groundwater do not appear to be creating unacceptable risks in the other site media.

5.3.2 Compliance with ARARs

Under all five RAAs, the primary groundwater COCs, (TCE, PCE, DCE, and benzene) have the potential to meet Federal and State chemical-specific ARARs, through passive and/or active remedial approaches. Under RAAs 1, 2, and 3, contaminants may eventually meet chemical-specific ARARs via the passive remedial approach of natural attenuation. The primary COCs may as well, eventually meet ARARs via the active remedial approaches introduced under RAAs 4 and 5; however, very few active remedial actions can document that contaminated groundwaters have been remediated to drinking water standards.

RAAs 4 and 5 can be designed to meet applicable location- and/or action-specific ARARs. No location-specific ARARs apply to RAAs 1, 2, and 3. RAA 1 will not comply with the action-specific ARAR for groundwter corrective actions (15A NCAC 2L.0106-.0113). RAA 2 will require a variance to comply with this ARAR. RAA 3 will be designed to comply with this same ARAR.

5.3.3 Long-Term Effectiveness and Permanence

RAAs 4 and 5 appear to provide the greatest degree of long-term effectiveness and permanence. Of all the alternatives evaluated, RAA 1 will allow the most residual risk to remain at the site because it involves taking no action. The other RAAs will allow less residual risk to remain at the site because they involve, at a minimum, institutional controls. Compared to RAA 2, however, RAAs 3, 4, and 5 will mitigate residual risk to a greater extent because they involve monitored natural attenuation (RAA 3) and active groundwater remediation (RAAs 4 and 5). Regardless, the magnitude of residual risk associated with leaving contaminants untreated at the site is minimal (as discussed in Section 5.3.1).

The long-term effectiveness of RAAs 1, 2, and 3 rely on the effectiveness of natural attenuation at reducing VOC contamination. As previously noted, the extent to which natural attenuation may reduce contaminant levels, and the amount of time it will take, are difficult to predict. However, cleanup times under RAAs 4 and 5 are also very difficult to predict.

Active remediation may be considered a more reliable means for treating contaminants than passive remediation; however, RAAs 4 and 5 will only be adequate and reliable to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Similarly, the technology associated with RAA 5 may spread contaminants into the vadose zone. As a result, active remediation methods may not be completely reliable for extracting contaminants from the groundwater.

RAAs 2, 3, 4, and 5 all involve groundwater monitoring programs, and aquifer and land use restrictions. RAA 3 includes the most extensive monitoring program in order to identify the type and progress of natural attenuation processes that may be occurring. These controls have been proven in the past to be adequate and reliable means to manage the hazardous substances remaining on site. RAA 1, however, does not provide adequate or reliable controls. As a result, RAAs 2, 3, 4, and 5 mitigate human health exposure through the use of institutional controls, but RAA 1 does not. Also, the effectiveness of RAAs 3, 4, and 5 can be determined (via remedial action and monitoring) more often than the effectiveness of RAAs 1 and 2 can be determined.

All five RAAs require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. This review will no longer be necessary once ARARs are achieved.

5.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The treatment processes associated with RAAs 3, 4, and 5 will reduce the toxicity and volume of contaminated groundwater. The treatment processes associated with RAAs 3 and 4 are also expected to have irreversible effects. RAAs 1, 2, and 3 do not involve physical treatment processes. However, RAAs 1, 2, and 3 involve passive treatment processes in the form of the natural attenuation processes. Thus, groundwater contamination may undergo toxicity and volume reduction under RAAs 1, 2, and 3, but offer no reduction in plume mobility.

The RAAs differ significantly in the kind of residuals they will create after treatment. Structural residuals (monitoring wells) will remain at the site under all five of the RAAs. RAAs 1, 2, and 3; however, create no treatment residuals. RAAs 4 and 5, on the other hand, will create treatment residuals. The residuals associated with RAA 4 (sludge, off-gases, and treated groundwater) are more voluminous than the treatment residuals associated with RAA 5 (condensed vapor and spent carbon).

RAAs 4 and 5 satisfy the statutory preference for treatment via active remediation, while RAA 3 satisfies the statutory preference for treatment via the confirmed natural attenuation processes. Since treatment cannot be confirmed under RAAs 1 and 2, the statutory preference for treatment cannot be justified.

5.3.5 Short-Term Effectiveness

Implementation of RAAs 1, 2, and 3 does not pose substantial risks to the community or workers. Implementation of RAAs 4 and 5 may pose some risk to community and/or workers because they involve construction and operation of on-site treatment facilities.

The time for the natural attenuation processes associated with RAAs 1, 2, and 3 to be complete is unknown and difficult to estimate. Likewise, the time for RAAs 4 and 5 to be complete is unknown. Based on existing site and technology information, it appears that RAA 5 may require the least time.

5.3.6 Implementability

RAA 1 is the easiest to implement alternative. RAAs 2 and 3 are the next most implementable alternatives, followed by RAAs 4 and 5. RAAs 4 and 5 are the least implementable because they involve well installation and construction of a treatment system. In addition, the existing industrial setting of Site 86 may hinder construction of RAAs 4 and 5.

RAA 1 requires no O&M; while RAAs 2 and 3 require minimal O&M for the groundwater sampling and periodic well replacement. RAA 3 requires a slight increase in maintenance, as the monitoring requirements include both TCL VOCs and natural attenuation parameters. RAAs 4 and 5 require the most O&M. Compared to RAA 4, RAA 5 requires much less system O&M because the groundwater being treated is not lifted above the ground surface.

Under RAAs 4 and 5, there is the potential for inorganic precipitation and oxidation to clog the well screens necessitating frequent maintenance and possibly equipment replacement. Under RAA 5, this potential is greater because metals precipitation and oxidation will be enhanced by the injection of oxygen.

Under all five of the RAAs, additional remedial actions could potentially be implemented with relative ease, if necessary.

There are no equipment requirements associated with RAA 1. RAAs 2, 3, and 4 involve conventional equipment and services that should be readily available. The equipment associated with RAA 5 is not as conventional as the equipment associated with RAAs 2, 3, and 4; and it is only available through a limited number of vendors.

RAAs 1 and 2 may require a waiver of ARARs since contaminated groundwater will be left on site indefinitely at concentrations that exceed ARARs; while RAAs 4 and 5 will both require extensive coordination with the Base Public Works/Planning Department. Additionally, RAAs 2, 3, 4, and 5 will require semiannual submission of reports that document sampling and/or treatment results.

5.3.7 Cost

In terms of NPW, the no action alternative (RAA 1) would be the least expensive alternative to implement. The estimated NPW values in increasing order are: $0 (RAA 1), $400,000 (RAA 2), $960,000 (RAA 3), $1,440,000 (RAA 4), and $1,660,000 (RAA 5).

5.4 Reference

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

SECTION 5.0 TABLES

TABLE 5-1

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
OVERALL PROTECTIVENESS					
• Human Health	No measurable reduction in potential human health risks.	Institutional controls will reduce potential human health risks.	Provides overall protection of human health through natural attenuation, monitoring, and aquifer and land use restrictions.	Institutional controls and groundwater extraction/treatment will reduce potential human health risks.	Institutional controls, and in-well aeration will reduce potential human health risks.
• Environmental Protection	No measurable reduction in potential risks to ecological receptors.	No measurable reduction in potential risks to ecological receptors.	Provides overall protection of the environment through natural attenuation and monitoring.	Institutional controls and active groundwater treatment will reduce risks to ecological receptors.	Institutional controls and active groundwater treatment will reduce risks to ecological receptors.
COMPLIANCE WITH ARARs					
• Chemical-Specific ARARs	Contaminants may eventually meet the Federal and State ARARs through natural attenuation processes.	Contaminants may eventually meet the Federal and State ARARs through natural processes.	Natural attenuation is expected to achieve the ARARs over time.	Groundwater contamination may eventually meet Federal and State ARARs through active treatment.	Groundwater contamination may eventually meet Federal and State ARARs through active treatment.
• Location-Specific ARARs	Not applicable.	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	Will not meet groundwater corrective actoin State ARAR.	Will not meet groundwater corrective action State ARAR without a variance.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	The residual risk from untreated contaminants will be minimal. However, RAA 1 provides no active means for reducing residual risk.	Although residual risk from untreated contaminants will be minimal, it will remain on site under RAA 2. However, institutional controls should mitigate any residual risks that may exist.	Residual risks will be minimal; however, natural attenuation combined with monitoring and residential development restrictions should mitigate remaining residual risk.	Groundwater extraction/treatment should mitigate residual risk. However, due to the technical limitations associated with groundwater remediation, extraction/treatment is not expected to eliminate residual risk.	In-well aeration should mitigate residual risk. However, due to the technical limitations associated with groundwater remediation, in-well aeration is not expected to eliminate residual risk.
• Adequacy and Reliability of Controls	There are no controls associated with this alternative.	The monitoring program is adequate and reliable for determining the alternative's effectiveness. If enforced over time, aquifer and residential development restrictions are adequate and reliable for preventing human exposure to groundwater.	Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination, as well as, maintaining this alternative's effectiveness. If enforced over time, residential development restrictions are also adequate and reliable controls to eliminate the possibility of future groundwater exposure.	Once designed/sized in accordance with site-specific characteristics, extraction/treatment should be both adequate and reliable. The monitoring program is adequate and reliable for determining the alternative's effectiveness. If enforced over time, aquifer and residential development restrictions are adequate and reliable for preventing human exposure to groundwater.	Due to the limited commercial track record, the adequacy and reliability of in-well aeration is uncertain. The monitoring program is adequate and reliable for determining the alternative's effectiveness. If enforced over time, aquifer and residential development restrictions can be adequate and reliable for preventing human exposure to groundwater.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
LONG-TERM EFFECTIVENESS AND PERMANENCE (continued)					
• Need for 5-year Reviews	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	There is no physical treatment process associated with this alternative.	There is no physical treatment process associated with this alternative.	There is no physical treatment process associated with this alternative; however, natural attenuation will provide passive treatment.	The treatment process includes neutralization, precipitation, flocculation, sedimentation, and filtration as pretreatment for the air stripper; air stripping for VOC removal; and secondary treatment of air emission and groundwater via carbon adsorption.	The treatment process includes in-well aeration and off-gas carbon adsorption. This process strips VOCs from the groundwater and removes contaminants from the off-gas.
• Amount Destroyed or Treated	No destruction through treatment; however, natural attenuation processes are expected to reduce contaminant concentrations.	No destruction through treatment; however, natural attenuation processes are expected to reduce contaminant concentrations.	Natural attenuation is expected to treat and/or destroy the majority of the contamination.	Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be treated.	Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be treated.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (continued)					
• Reduction of Toxicity, Mobility, or Volume Through Treatment	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	The groundwater treatment processes are expected to reduce toxicity and volume of contaminants in the groundwater, and the extraction wells will reduce the mobility of the plume.	The in-well aeration system is expected to reduce the toxicity, mobility, and volume of the plume.
• Irreversibility of the Treatment	Not applicable.	Not applicable.	Not applicable.	Air stripping will have irreversible results.	In-situ air stripping and off-gas carbon adsorption will have irreversible results.
• Residuals Remaining After Treatment	Not applicable.	Not applicable.	Not applicable.	Treatment residuals may include sludge, spent carbon, and treated groundwater. The sludge should be non-hazardous, the spent carbon will require disposal or regeneration, and the treated groundwater will be within acceptable groundwater discharge limits.	Treatment residuals will include the small amount of liquid left in the knockout tanks and spent carbon. The liquid should be non-hazardous, but the spent carbon will contain adsorbed contaminants requiring disposal or regeneration.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (continued)					
• Statutory Preference for Treatment	Since no means are provided to measure the effects/progress of natural attenuation, the statutory preference for treatment cannot be justified.	Since no means are provided to measure the effects/progress of natural attenuation, the statutory preference for treatment cannot be justified.	If the natural attenuation processes are confirmed through monitoring, the statutory preference for treatment will be satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS					
• Community Protection	Potential risks to the community will not be increased.	Potential risks to the community will not be increased during implementation.	Potential risks to the community will not be significantly increased.	Potential risks to the community will be increased during installation of the extraction/treatment system and during system operation. Proper site controls will be necessary during system installation and operation.	Potential risks to the community will be increased during installation of the in-well aeration system and during system operation. Proper site controls will be necessary during system installation and operation.
• Worker Protection	No risks to workers.	No risks to workers.	No significant risks to workers; however, adequate personal protective equipment may be necessary.	Potential risks to workers will be increased; worker protection is required.	Potential risks to workers will be increased; worker protection is required.
• Environmental Impact	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
SHORT-TERM EFFECTIVENESS (Continued)					
• Time Until Action is Complete	Unknown.	Unknown; 30 years of monitoring has been assumed for cost estimating purposes.	Unknown; 30 years of monitoring has been assumed for cost estimating purposes.	Unknown; 30 years has been assumed for cost estimating purposes.	Unknown; 30 years has been assumed for cost estimating purposes.
IMPLEMENTABILITY					
• Ability to Construct and Operate	Not applicable.	Based on past experience, groundwater sampling and residential development and aquifer use restrictions are easily implemented.	Based on past experience, groundwater sampling and aquifer use restrictions are easily implemented.	Based on past experience, an extraction/treatment system will be easy to construct and operate. Disposal of treatment residuals and inorganics precipitation on the well screens may make system operation challenging. The fact that groundwater must be lifted above the ground surface also complicates system operation. The industrial setting of the site may hinder system construction.	Carbon replacement and inorganics precipitation on the well screens may make system operation more challenging. The fact that groundwater will not be lifted above the ground surface simplifies system operation. The industrial setting of the site may hinder system construction.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
IMPLEMENTABILITY (Continued)					
• Reliability of Technology	Not applicable.	Groundwter sampling is a reliable monitoring technology.	Groundwater sampling techniques, together with documentation of natural attenuation processes, provide for a reliable remedial technology.	Inorganics may precipitate on the well screens creating the need for well replacement. Also, the long operation time for the system may necessitate equipment replacement.	In-well aeration has not been widely demonstrated so its reliability is uncertain. However, there are several successful full scale applications. Inorganics may precipitate on the well screens necessitating well replacement.
• Ease of Undertaking Additional Remedial Actions	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.
• Ability to Monitor Effectiveness	No monitoring plan. Failure to detect contamination could result in human and/or environmental exposure.	Monitoring plan designed to detect contaminants before significant exposure can occur. The monitoring will not indicate the progress or processes related to natural attenuation.	Monitoring plan designed to detect contaminants before significant exposure can occur. Natural attenuation parameters and groundwater modeling establish predictable alternative effectiveness.	Monitoring plan designed to detect contaminants before significant exposure can occur.	Monitoring plan designed to detect contaminants before significant exposure can occur.
• Availability of Services and Equipment	No services or equipment required.	Services and equipment are readily available.	Services and equipment are readily available.	Services and equipment are readily available.	Services and equipment are available through a number of vendors.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 86, TANK AREA AS491-AS421 AT MCAS
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Well Aeration
IMPLEMENTABILITY (Continued)					
• Requirements for Agency Coordination	May require a waiver of ARARs since contaminated groundwater will be left on site.	Must submit semiannual reports to document sampling.	No significant requirements; however, semiannual reports will document results.	Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.	Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.
COST (Net Present Worth)	**$0**	**$400,000**	**$960,000**	**$1,440,000**	**$1,660,000**

TABLE 5-2
ESTIMATED COSTS FOR GROUNDWATER RAA No. 2

GROUNDWATER RAA No. 2: INSTITUTIONAL CONTROLS
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCB CAMP LEJEUNE, NC

MONITORING 9 EXISTING WELLS

ANNUAL O&M COSTS

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M							
Labor	Hours	80	$40	$3,200		2 sampling events/yr, 2 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,508	$3,016		Includes minivan rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$292	$584		Includes lodging and meals for 2 people	Engineering Estimate - Previous Projects
Laboratory Analysis & Data Validation							Basic Ordering Agreement
VOA	Sample	22	$179	$3,938		9 samples/1 duplicate sample /1 MS/MSD sample, twice yearly	Basic Ordering Agreement
Equipment & Supplies	Sample Event	2	$610	$1,220		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$332	$664		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$6,301	$6,301		Equal annual cost of replacing 9 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$670	$670			Engineering Estimate; Table 5-2B
Total Groundwater Monitoring O&M Costs					$25,592		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$0**	
TOTAL ANNUAL O&M COSTS	**$26,000**	30 years of monitoring
PRESENT WORTH VALUE	**$400,000**	Based on a discount rate of 5%

TABLE 5-2A
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT COSTS

GENERAL ASSUMPTIONS
6 intermediate monitoring wells (55-ft deep) will be replaced
3 deep monitoring wells (100-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation (0-50 f	LF	$31.50	450	$14,175.00
Type II Well installation (>50 ft	LF	$41.50	180	$7,470.00
2" PVC sch. 40 riser	LF	$1.25	447	$558.75
2" PVC sch. 40 screen	Each	$20.00	21	$420.00
Protective cover	Each	$140.00	9	$1,260.00
Drums	Each	$42.00	84	$3,528.00
Well development	Hour	$65.00	27	$1,755.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	10	$950.00
Geologist labor	Hour	$40.00	100	$4,000.00
Geologist travel	Each	$2,400.00	1	$2,400.00
Geologist per diem	Day	$73.00	10	$730.00

Well Replacement Costs	$37,947
Total Present Worth (5% discount rate, 5 replacement events, 30yrs)	$96,787
Equal Annual Cost (5% discount rate, 30 years)	$6,301

TABLE 5-2B
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REDEVELOPMENT

GENERAL ASSUMPTIONS

Redevelop 11 monitoring wells every 5 years for 30 years

Item	Units	Unit Cost	No. of Units	Total
Labor (2 people)	Hr	$40.00	80	$3,200.00
Equipment	Ls	$200.00	1	$200.00
Travel	Day	$65.00	3	$195.00
Per Diem (2 people x $73.00/day)	Day	$146.00	3	$438.00

Redevelopment Costs Per Event	$4,033
Total Present Worth (5% discount rate, 5 redevelopment events, 30y	$10,287
Equal Annual Cost (5% discount rate, 30 years)	$670

TA. 5-3

ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: NATURAL ATTENUATION
OU No 6, SITE 86 - ABOVE GROUND STORAGE TANK AREA
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 13 EXISTING & 2 NEW WELLS

Jun-98

DIRECT AND INDIRECT CAPITAL COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
MONITORING WELLS & SOIL BORINGS							
Additional Well Installation	LS	1	$12,395	$12,395		Install 1 intermediate well and 1 deep well	Engineering Estimates - Table 5-3A
Total Well Installation Capital Costs					$12,395		
NATURAL ATTENUATION STUDIES							
Initial Field Effort	LS	1	$ 20,712	$20,712		Collection of soil, soil gas, and groundwater samples	Engineering Estimates - Table 5-3C
Modeling, Data Evaluation and Analysis	LS	1	$25,000	$25,000			Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$10,000	$10,000			Engineering Estimates - Previous Projects
Reporting	LS	1	$10,000	$10,000			Engineering Estimates - Previous Projects
Contingency	LS	1	$4,966	$4,966		15% of direct capital costs	Engineering Estimates - Previous Projects
Total Natural Attenuation Study Capital Costs					$70,678		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					$ 83,073		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M							
Labor	Hours	48	$32	$1,536		2 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Table 5-3D
Travel	Sample Event	1	$1,508	$1,508		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table 5-3D
Per Diem	Sample Event	1	$292	$292		Includes lodging and meals for 2 people	Engineering Estimate - Table 5-3D
Laboratory Analysis & Data Validation							
Intrinsic Remed. Parameters	Sample	17	$ 631.79	$10,740		15 samples/1 duplicate samples /1 MS/MSD samples	Basic Ordering Agreement - Table 5-3E
Equip. & Supplies	Sample Event	1	$552	$552		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table 5-3D
Shipping	Sample Event	1	$332	$332		2 coolers per day for 2 days; $83/cooler	Engineering Estimate - Table 5-3D
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$8,903	$8,903			Engineering Estimate; Table 5-3B
Well Redevelopment	Year	1	$670	$670			Engineering Estimate; Table 5-3F
Model Updates & Reporting	Year	1	$20,000	$20,000			
Total Groundwater Monitoring O&M Costs (1 to 5 years)					$92,511	Quarterly sampling will be performed for the first 5 years	
Total Groundwater Monitoring O&M Costs (6 to 30 years)					$56,590	Semi-annual sampling will be performed for the remaining 25 yrs	

TABLE 5-3 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: NATURAL ATTENUATION
OU No 6, SITE 86 - ABOVE GROUND STORAGE TANK AREA
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

MONITORING 13 EXISTING & 2 NEW WELLS
Jun-98

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$ 83,000	
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)	$93,000 $57,000	
PRESENT WORTH VALUE	$959,000	Based on a discount rate of 5%

TABLE 5-3A
COST ESTIMATE ASSUMPTIONS FOR ADDITIONAL MONITORING WELL INSTALLATION

GENERAL ASSUMPTIONS

1 intermediate monitoring well (55-ft deep)

1 deep monitoring well (100-feet deep)

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation (0-50 ft)	LF	$31.50	100	$3,150.00
Type II Well installation (>50 ft)	LF	$41.50	55	$2,282.50
2" PVC sch. 40 riser	LF	$1.25	125	$156.25
2" PVC sch. 40 screen	Each	$20.00	3	$60.00
Protective cover (Flush mounts)	Each	$140.00	2	$280.00
Drums	Each	$42.00	20	$840.00
Well development	Hour	$65.00	6	$390.00
Temp. decon. pad	Each	$200.00	1	$200.00
Misc. expenses	Each	$1,000.00	1	$1,000.00
Contractor per diem	Day	$95.00	2	$190.00
Geologist labor	Hour	$40.00	20	$800.00
Geologist travel	Each	$2,400.00	1	$2,400.00
Geologist per diem	Day	$73.00	2	$146.00
Well Installation Costs				$12,395

TABLE 5-3B
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT COSTS

GENERAL ASSUMPTIONS

1 shallow monitoring well (15-ft deep) will be replaced
11 intermediate monitoring wells (55-ft deep) will be replaced
3 deep monitoring wells (100-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation (0-50 ft)	LF	$31.50	715	$22,522.50
Type II Well installation (>50 ft)	LF	$41.50	205	$8,507.50
2" PVC sch. 40 riser	LF	$1.25	615	$768.75
2" PVC sch. 40 screen	Each	$20.00	32	$640.00
Protective cover	Each	$140.00	15	$2,100.00
Drums	Each	$42.00	108	$4,536.00
Well development	Hour	$65.00	45	$2,925.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	15	$1,425.00
Geologist labor	Hour	$40.00	150	$6,000.00
Geologist travel	Each	$2,400.00	1	$2,400.00
Geologist per diem	Day	$73.00	15	$1,095.00

Well Replacement Costs	$53,620
Total Present Worth (5% discount rate, 5 replacement events, 30yrs)	$136,763
Equal Annual Cost (5% discount rate, 30 years)	$8,903

TABLE 5-3C
ESTIMATED COSTS FOR INITIAL FIELD EFFORT

Item	Units		Unit Cost	Quantity		Subtotal	Remarks
Geoprobe Rig	Day	$	1,500.00	2	$	3,000.00	Engineering Estimate
Equipment	LS	$	551.79	1	$	551.79	Table 5-3D
Water Analysis	Suite	$	631.79	11	$	6,949.69	Table 5-3E
Soil Analysis	Suite	$	212.27	10	$	2,122.70	Table 5-3E
Labor	Hour	$	32.00	160	$	5,120.00	Engineering Estimate
Travel	LS	$	1,800.00	1	$	1,800.00	Engineering Estimate
Per Diem (2 people)	Day		$146.00	8	$	1,168.00	Engineering Estimate
				Total	$	20,712.00	

TABLE 5-3D
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS

- Groundwater will be sampled quarterly for the first 5 years, then semiannually thereafter
- 15 wells will be sampled for intrinsic remediation parameters

LABOR	48	hours/event
No. of people:	2	
Days required:	2	
Hours per day:	10	
Travel Time/person	4	
LABOR COST	$1,920	/event
TRAVEL	$1,508	/event
No. of people:	2	
Days required:	2	
Airfare (roundtrip PIT-OAJ, full fare)	$689.00	
Mini-van rental	$65.00	
PER DIEM	$292.00	/event
No. of people:	2	
Days required:	2	
Lodging (per night)	$47.00	
Meals (per day)	$26.00	

ITEM	UNIT RATE	UNIT	No. OF UNITS	TOTAL
Conductivity Meter	$3.86	/Day	2	$7.72
pH Meter	$6.35	/Day	2	$12.70
Turbidity Meter	$9.67	/Day	2	$19.34
Hydrogen Ion Meter	$80.00	/Day	2	$160.00
D.O. Meter	$13.23	/Day	2	$26.46
Perstaltic Pump	$6.62	/Day	2	$13.24
P.E. Tubing	$21.25	/100 feet	2	$42.50
Silicon Tubing	$2.75	/foot	2	$5.50
P.E. Squeeze Bottles	$.06	/Day	2	$.12
Garbage Bags	$.16	Each	5	$.80
Inner Gloves	$8.97	/Box	1	$8.97
Paper Towels	$.81	Roll	4	$3.24
Markers	$.60	Each	2	$1.20
Equipment Shipping	$50.00	/Package	5	$250.00
			TOTAL:	$551.79

TABLE 5-3E
ESTIMATED ANALYTICAL PARAMETER COSTS FOR INTRINSIC REMEDIATION MONITORING

Parameters	Unit Price(1)	Validation Price	Total
Water Analysis			
Diss. Oxygen	Field (2)	--	--
Nitrate & Nitrite	$ 20.03	$ 6.67	$ 26.70
Iron (II)	$ 45.00	$ 7.00	$ 52.00
Iron (III)	$ 45.00	$ 7.00	$ 52.00
Sulfate	$ 13.39	$ 6.33	$ 19.72
Sulfide	$ 17.41	$ 6.33	$ 23.74
Methane	$ 140.00	$ 13.50	$ 153.50
ReDox	Field	--	--
Major Cations	$ 55.00	$ 15.00	$ 70.00
pH	Field	--	--
Temperature	Field	--	--
TOC (water)	$ 24.13	$ 6.33	$ 30.46
Alkalinity	$ 9.93	$ 6.17	$ 16.10
Chloride	$ 12.84	$ 6.33	$ 19.17
VOAs	147.73	20.67	$ 168.40
	TOTAL		$ 631.79
Soil Analysis			
VOCs	$ 160.44	$ 20.50	$ 180.94
TOC	$ 25.00	$ 6.33	$ 31.33
Moisture (3)	--	--	--
	TOTAL		$ 212.27

NOTES
(1) Costs based on laboratory quotes and LANTDIV bidding prices.
(2) The cost for field analysis is included in equipment and labor costs for groundwater sampling.
(3) No charge, as moisture content is included in other analyses
(4) On-site mobile laboratory used for soil gas analysis

TABLE 5-3F
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REDEVELOPMENT

GENERAL ASSUMPTIONS

Redevelop 11 monitoring wells every 5 years for 30 years

Item	Units	Unit Cost	No. of Units	Total
Labor (2 people)	Hr	$40.00	80	$3,200.00
Equipment	Ls	$200.00	1	$200.00
Travel	Day	$65.00	3	$195.00
Per Diem (2 people x $73.00/day)	Day	$146.00	3	$438.00

Redevelopment Costs Per Event	$4,033
Total Present Worth (5% discount rate, 5 redevelopment events, 30yrs)	$10,287
Equal Annual Cost (5% discount rate, 30 years)	$670

TABLE 5-4
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCB CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 9 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$15,000	$15,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$12,000	$12,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$12,500	$12,500			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$7,000	$7,000			Engineering Estimate- Previous Projects
Total General Costs					$56,500		
SITE WORK							
Site Work During System Installation:							
Saw Cutting Through Asphalt	LF	300	$5	$1,500		Assuming asphalt is 8" thick	Means Site 1996, 020-728 & Estimate
Remove & Reset Portion of Existing Fence	LF	20	$14	$280			Means Site 1996, 020-550 & Estimate
Piping Trench for the Collection Line	LF	560	$4	$2,240		Includes excavation, removal, backfill, and tamping	Means Site 1996, A12.73-110 & Estimate
Piping Trench for the Discharge Line	LF	120	$4	$480		Includes excavation, removal, backfill, and tamping	Means Site 1996, A12.73-110 & Estimate
Excavation for Treatment Plant Slab	CY	50	$12	$600		Roughly 25' x 25' x 2'excavation	Means Site 1996, 022-200 & Estimate
Backfill Around Treatment Plant Slab	CY	30	$5	$150		Roughly 5' x 2' x 80' around plant	Means Site 1996, 022-226 & Estimate
Cut and Fill for Driveway to Treatment Plant	CY	300	$5	$1,500		Includes excavation, water wagon, backfill, and tamping	Means Site 1996, A12.1-214 & Estimate
Construct Asphalt Driveway	LF	20	$67	$1,340		Assuming asphalt is 8" thick	Means Site 1996, A12.5-111 & Estimate
Water Connection at Treatment Plant	LF	100	$8	$800		Includes trenching & laying a 1" copper line	Means Site 1996, 026-662 & 022-258
Overhead Electrical to Treatment Plant	LF	75	$25	$1,875		Includes overhead routing and poles	Means Site 1996, 167-100 & Estimate
Erosion Protection at Discharge Point	CY	5	$62	$310		For erosion protection around headwall	Engineering Estimate- Previous Projects
Site Restoration:							
Top Dressing Around Treatment Plant	CY	50	$40	$2,000		Around 25' x 25' treatment plant slab, 6" thick	Means Site 1996, 022-286 & Estimate
Fine Grading and Seeding for Revegetation	SY	380	$2	$760		Revegetation for 1 acre that was cleared	Means Site 1996, 022-286 & Estimate
Pavement Replacement Over Trench	SY	300	$46	$13,800		Assuming asphalt pavement 8" thick	Means Site 1996, 025-104 & Estimate
Total Site Work Costs					$27,635		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCB CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 9 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
CONCRETE/STRUCTURAL							
Pre-fab. Bldg. for Metals Pretreatment Plant	EA	1	$30,000	$30,000		25' x 25' building	Engineering Estimate- Previous Projects
Installation of Building	EA	1	$7,500	$7,500			Engineering Estimate- Previous Projects
Foundation for Building	EA	1	$3,848	$3,848		25' x 25' on-grade slab	Engineering Estimate- Previous Projects
Total Concrete/Structural Costs					$41,348		
EXTRACTION WELLS							
Intermediate Extraction Well Installation	LF	180	$450	$81,000		6" stainless steel, incl installation of pumps and appurtenances	Engineering Estimate- Previous Projects
Well Development	EA	3	$375	$1,125			Engineering Estimate- Previous Projects
Extraction Well Pumps	EA	3	$2,550	$7,650		Includes well pump, level tracking device, and regulator	Vendor Quote
Appurtenances	EA	3	$1,000	$3,000			Vendor Quote
Manholes (Materials & Installation)	EA	1	$1,754	$1,754		Includes materials, excavation, backfill, trim, and compaction	Means Site 1996, A12.3-710 & Estimate
Total Extraction Well Costs					$94,529		
PIPING SYSTEM							
2" PVC Line for Collection	LF	560	$5	$2,800		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
2" PVC Line for Discharge	LF	120	$5	$600		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
4" PVC Containment Line for Recovery	LF	560	$8	$4,480		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
Fittings	LS	1	$510	$510		Assume 15% of Total Piping Cost	Engineering Estimate- Previous Projects
Total Piping System Costs					$8,390		
TREATMENT EQUIPMENT							
Package VOC and Solids Removal System	EA	1	$37,675	$37,675		Includes air stripper, solids filter, electric submersible pumps, all controls, and shipping (system skid mounted & enclosed)	Vendor Quote
Metals Pretreatment System	EA	1	$38,000	$38,000		Includes surge tank, clarifier, filter press, etc.	Engineering Estimate- Previous Projects
Flowmeter	EA	1	$1,500	$1,500			Engineering Estimate- Previous Projects
Installation of Equipment	LS	1	$4,000	$4,000		Incl. unloading crane, pump installation, hookups, and startup	Vendor Estimate
Piping and Fittings	LS	1	$9,794	$9,794		Assume 25% of equipment cost	Engineering Estimate- Previous Projects
Carbon Treatment Unit	EA	2	$1,000	$2,000			Engineering Estimate- Previous Projects
Total Treatment Plant Equipment Costs					$92,969		
TOTAL DIRECT CAPITAL COSTS					$321,371		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCB CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 9 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$38,564	$38,564		12% of Total Direct Cost	Engineering Estimate
Pump Test	LS	1	$15,000	$15,000			Engineering Estimate
3D Groundwater Modeling	Hour	300	$40	$12,000			Engineering Estimate
Design and Construction Administration	LS	1	$48,206	$48,206		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$48,206	$48,206		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$48,206	$48,206		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$210,181		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	80	$40	$3,200		9 samples, 2 days, 10 hrs/day/person, 2 people	Engineering Estimate
Travel	Sample Event	2	$1,508	$3,016		Includes travel-airfare for 2 people and truck rental	Engineering Estimate
Per Diem	Sample Event	2	$292	$584		2 days/sample event, $73/day/person, 2 people	Engineering Estimate
Laboratory Analysis & Data Validation							
VOCs	Sample	22	$179	$3,938		9 samples / 1 duplicate / 1 MS/MSD / twice yearly	Basic Ordering Agreement
Equipment and Supplies	Sample Event	2	$610	$1,220		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$332	$664		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$6,301	$6,301		Equal annual cost of replacing 9 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$670	$670			Engineering Estimate; Table 5-2B
Total Groundwater Monitoring O&M Costs					$25,592		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCB CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 9 EXISTING WELLS

ANNUAL O&M COSTS

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Labor for Plant O&M	Week	52	$120	$6,240		4 hrs/wk, 52 weeks/yr, at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$240	$2,880		8 hr/month, 12 months/yr, at $30/hr	Engineering Estimate
Air Sampling - Analysis	Sample	24	$200	$4,800			Engineering Estimate
Effluent Sampling - Analysis	Sample	24	$300	$7,200			Engineering Estimate
Carbon Replacement	Unit	2	$1,000	$2,000		Replacement of both units yearly	Engineering Estimate
Sludge Disposal	Month	12	$300	$3,600		2 drums/month at $150/drum disposal costs	Engineering Estimate
Electricity	Month	12	$150	$1,800		24 hr/day, 365 days/year operation	Means Site 1996, 010-034 & Estimate
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
Total Treatment System O&M Costs					$33,520		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$532,000**	
TOTAL ANNUAL O&M COSTS	**$59,000**	Assuming 30 Years of Operation
PRESENT WORTH VALUE	**$1,439,000**	Based on a discount rate of 5 %

TABLE 5-5
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCAS NEW RIVER, NC

5 AERATION WELLS
MONITORING 9 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$15,000	$15,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$12,000	$12,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$12,500	$12,500			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$7,000	$7,000			Engineering Estimate- Previous Projects
Pilot Study	LS	1	$300,000	$300,000			Engineering Estimate- Previous Projects
Total General Costs					$356,500		
SITE WORK							
Water Connection at Treatment Trailer	LF	100	$8	$800		Includes trenching & laying a 1" copper line	Means Site 1996, 026-662 & 022-258
Overhead Electrical to Treatment Trailer	LF	75	$25	$1,875		Includes overhead routing and poles	Means Site 1996, 167-100 & Estimate
Total Site Work Costs					$2,675		
AERATION SYSTEM							
NoVOCs™ System	EA	1	$250,000	$250,000	$250,000	Includes, well drilling, installation, and development; mechanical, electrical & off-gas treatment equipment; trenching & air line install., backfilling & asphalt repair; labor for design spec.'s & drawings, oversight of installation, startup, & technical support	Vendor Quote
TOTAL DIRECT CAPITAL COSTS:					$609,175		

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$73,101	$73,101		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$91,376	$91,376		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$91,376	$91,376		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$255,854		

TABLE 5-5 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

5 AERATION WELLS
MONITORING 9 EXISTING WELLS

GROUNDWATER RAA No. 5: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 86 - ABOVEGROUND STORAGE TANK AREA
MCAS NEW RIVER, NC

ANNUAL O&M COSTS

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	80	$40	$3,200		2 sample events, 2 days, 10 hrs/day/person, 2 people	Engineering Estimate
Travel	Sample Event	2	$1,508	$3,016		Includes travel-airfare for 2 people and truck rental	Engineering Estimate
Per Diem	Sample Event	2	$292	$584		2 days/sample event, $73/day/person, 2 people	Engineering Estimate
Laboratory Analysis & Data Validation							
VOCs	Sample	22	$179	$3,938		9 samples / 1 duplicate / 1 MS/MSD twice yearly	Basic Ordering Agreement
Supplies & Equipment	Sample Event	2	$610	$1,220		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$292	$584		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$6,301	$6,301		Equal annual cost of replacing 9 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$670	$670			Engineering Estimate; Table 5-2B
TOTAL GROUNDWATER MONITORING O&M COSTS					$25,512		
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Utilities	Yr	1	$8,400	$8,400		Electric service at $0.10/Kwh and phone service	Vendor Quote
Maintenance	Yr	1	$1,000	$1,000		Routine repairs and preventative maintenance	Vendor Quote
Labor	Yr	1	$9,000	$9,000		Monthly inspections	Vendor Quote
Off-gas Treatment	Yr	1	$3,200	$3,200		Carbon replacement	Vendor Quote
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL TREATMENT SYSTEM O&M COSTS					$26,600		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$865,000**	
TOTAL ANNUAL O&M COSTS	**$52,000**	Assuming 30 Years of Operation
PRESENT WORTH VALUE	**$1,664,000**	Based on a discount rate of 5 %

:water Exposure Risk-Based A ...
.03 Site 86, Aboveground Stor ... rea
ity Study
, New River, North Carolina
Residential Child

	Action Level (mg/L)		Noncancer Risks			Total Noncancer Risks	Cancer Risks			Total Cancer Risks
	Noncarcinogenic	Carcinogenic	Ingestion	Dermal Contact	Inhalation		Ingestion	Dermal Contact	Inhalation	
chloroethene (total)	0.141	NA	1.0E+00	3.1E-02	—	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
roethene	0.09	1.6	9.6E-01	4.8E-02	—	1.0E+00	9.6E-05	4.8E-06	2.6E-09	1.0E-04
ne	30	0.6	0.0E+00	0.0E+00	1.0E+00	1.0E+00	9.5E-05	6.3E-06	8.5E-08	1.0E-04
hloroethene	0.14	0.31	8.9E-01	1.3E-01	—	1.0E+00	8.8E-05	1.2E-05	1.3E-09	1.0E-04
ony	0.0063	NA	1.0E+00	1.3E-02	0.0E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
c	0.0047	0.012	1.0E+00	1.3E-02	0.0E+00	1.0E+00	9.9E-05	1.2E-06	0.0E+00	1.0E-04
	4.7	NA	1.0E+00	1.3E-02	0.0E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Level (mg/L) = (C ingestion + C dermal contact + C inhalation)

stion (mg/L) = TR or HI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD
mal contact (mg/L) = TR or HI * BW * ATc or ATnc * DY / SA * PC * ET * EF * ED * CF * CSF or 1/RfD
lation (mg/L) = TR or HI * ATc or ATnc * DY / ED * ET * shower concentration * CSF or 1/RfC

:	inputs
= conc. in water from ingestion exposure (mg/l)	calculated
w = child daily water ingestion rate (L/Day)	1
= child exposure frequency (days/yr)	350
) = child exposure duration (yr)	6
V = child body weight (kg)	15
c = averaging time for carcinogen (yr)	70
nc = averaging time for noncarcinogen (yr)	6
Y = days per year (day/year)	365
SF = cancer slope factor (mg/kg-day)-1	specific
fD = reference dose (mg/kg-day)	specific

Where:	Inputs
C = conc. in water from d. contact exposure (mg/l)	calculated
SA = child skin surface available for contact (cm2)	10000
PC = contaminant specific dermal permability (cm/hr)	Specific
ET = child exposure time (hours/day)	0.25
EF = child exposure frequency (days/yr)	350
ED = child exposure duration (years)	6
CF = volumetric conversion factor for water (1liter/1000 cm3)	0.001
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic effects	1

The shower concentration is calculated from the Foster et al. shower model
RfC = inhalation reference concentration

tion

C	Concentration Noncarcinogen (mg/l)	Concentration Carcinogen (mg/l)	Ingestion Rate (L/day) Child	Exposure Frequency (day/year) Child	Exposure Duration (year) Child	Body Weight (kg) Child	Average Carc Time (days)	Carc Dose (mg/kg-day) Child	Slope Factor (mg/kg-day)-1	Carcinogenic Risk Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Child	Reference Dose (mg/kg-day)	Noncarcinogenic Risk Child
Dichloroethene (total)	0.141	NA	1	350	6	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	9.0E-03	9.0E-03	1.0E+00
loroethene	0.090	1.6	1	350	6	15	25550	8.8E-03	1.1E-02	9.6E-05	2190	5.8E-03	6.0E-03	9.6E-01
ene	30.000	0.6	1	350	6	15	25550	3.3E-03	2.9E-02	9.5E-05	2190	1.9E+00	0.0E+00	0.0E+00
achloroethene	0.140	0.31	1	350	6	15	25550	1.7E-03	5.2E-02	8.8E-05	2190	8.9E-03	1.0E-02	8.9E-01
nony	0.006	NA	1	350	6	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	4.0E-04	4.0E-04	1.0E+00
nic	0.005	0.012	1	350	6	15	25550	6.6E-05	1.5E+00	9.9E-05	2190	3.0E-04	3.0E-04	1.0E+00
	4.700	NA	1	350	6	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	3.0E-01	3.0E-01	1.0E+00

nal Contact

C	Concentration Noncarcinogen (mg/l)	Concentration Carcinogen (mg/l)	Surface Area (cm2) Child	Dermal Permeability (cm/hr)	Exposure Time (hours/day) Child	Exposure Frequency (days/yr) Child	Exposure Duration (years) Child	Volumetric Conversion (L/m3)	Body Weight (kg) Child	Averaging Carc Time (days)	Carc Dose (mg/kg-day) Child	Dermal Adjust. Slope Factor (mg/kg-day)-1	Carcinogenic Risk Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Child	Dermal. Adjust. Reference Dose (mg/kg-day)	Noncarc Risk Child
Dichloroethene (total)	0.141	NA	10000	1.00E-02	0.25	350	6	0.001	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	2.3E-04	7.2E-03	3.1E-02
loroethene	0.090	1.6	10000	1.60E-02	0.25	350	6	0.001	15	25550	3.5E-04	1.4E-02	4.8E-06	2190	2.3E-04	4.8E-03	4.8E-02
zene	30.000	0.6	10000	2.10E-02	0.25	350	6	0.001	15	25550	1.7E-04	3.6E-02	6.3E-06	2190	1.0E-01	0.0E+00	0.0E+00
achloroethene	0.140	0.31	10000	4.50E-02	0.25	350	6	0.001	15	25550	1.9E-04	6.5E-02	1.2E-05	2190	1.0E-03	8.0E-03	1.3E-01
mony	0.006	NA	10000	1.00E-03	0.25	350	6	0.001	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	1.0E-06	8.0E-05	1.3E-02
nic	0.005	0.012	10000	1.00E-03	0.25	350	6	0.001	15	25550	1.6E-07	7.5E+00	1.2E-06	2190	7.5E-07	6.0E-05	1.3E-02
	4.700	NA	10000	1.00E-03	0.25	350	6	0.001	15	25550	0.0E+00	0.0E+00	0.0E+00	2190	7.5E-04	6.0E-02	1.3E-02

lation

C	Concentration (mg/l)	Concentration mg/kg/shwr	Exposure Duration years	Exposure Frequency shwr/year	Avg. Time noncarc. days	Avg. Time carc. days	Noncarc. Dose mg/kg/d	Carc. Dose mg/kg/d	Inhalation Reference Conc. mg/kg/d	Inhalation Potency Factor (mg/kg/d)^-1	Noncarc. Risk	Cancer Risk
for metals												
-Dichloroethene (total)	0.141	9.4E-06	6	350	2190	25550	9.0E-06	7.7E-07	0.0E+00	0.0E+00	—	0.0E+00
hloroethene	0.09	5.4E-06	6	350	2190	25550	5.1E-06	4.4E-07	0.0E+00	6.0E-03	—	2.6E-09
zene	30	1.8E-03	6	350	2190	25550	1.7E-03	1.5E-04	1.7E-03	2.9E-02	1.0E+00	4.3E-06
zene	0.6	3.6E-05	6	350	2190	25550	3.4E-05	2.9E-06	1.7E-03	2.9E-02	2.0E-02	8.5E-08
achloroethene	0.14	7.7E-06	6	350	2190	25550	7.4E-06	6.3E-07	0.0E+00	2.0E-03	—	1.3E-09

Groundwater Exposure Risk-Based Act
CTO-303 Site 86, Aboveground Storage ...ea
Feasibility Study
MCAS, New River, North Carolina
Future Residential Adult

COPC	Action Level (mg/L) Noncarcinogenic	Action Level (mg/L) Carcinogenic	Noncancer Risk Ingestion	Noncancer Risk Dermal Contact	Noncancer Risk Inhalation	Total Noncancer Risk	Cancer Risk Ingestion	Cancer Risk Dermal Contact	Cancer Risk Inhalation	Total Cancer Risk
1,2-Dichloroethene (total)	0.33	NA	1.0E+00	3.6E-02	—	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Trichloroethene	0.21	0.75	9.6E-01	5.5E-02	—	1.0E+00	9.7E-05	5.6E-06	5.1E-09	1.0E-04
Benzene	190	0.28	0.0E+00	0.0E+00	1.0E+00	1.0E+00	9.5E-05	7.2E-06	3.3E-08	1.0E-04
Tetrachloroethene	0.32	0.145	8.8E-01	1.4E-01	—	1.0E+00	8.9E-05	1.4E-05	2.4E-09	1.0E-04
Antimony	0.015	NA	1.0E+00	1.5E-02	0.0E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Arsenic	0.011	0.0056	1.0E+00	1.4E-02	0.0E+00	1.0E+00	9.9E-05	1.4E-06	0.0E+00	1.0E-04
Iron	11	NA	1.0E+00	1.4E-02	0.0E+00	1.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Action Level (mg/L) = (C ingestion + C dermal contact + C inhalation)

C ingestion (mg/L) = TR or HI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD
C dermal contact (mg/L) = TR or HI * BW * ATc or ATnc * DY / SA * PC * ET * EF * ED * CF * CSF or 1/RfD
*C inhalation (mg/L) = TR or HI * ATc or ATnc * DY / ED * ET * shower concentration * CSF or 1/RfC*

Where:	Inputs
C = conc. in water from ingestion exposure (mg/l)	calculated
IRw = adult daily water ingestion rate (L/Day)	2
EF = adult exposure frequency (days/yr)	350
ED = adult exposure duration (yr)	30
BW = adult body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (day/year)	365
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific

Where:	Inputs
C = conc. in water from d. contact exposure (mg/l)	Calculated
SA = adult skin surface area (cm2)	23000
PC = contaminant specific dermal permability (cm/hr)	Specific
ET = adult exposure time (hours/day)	0.25
EF = adult exposure frequency (days/yr)	350
ED = adult exposure duration (years)	30
CF = volumetric conversion factor for water (1liter/1000 cm3)	0.001
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic affects	1

The shower concentration is calculated from the Foster et al. shower model
RfC = inhalation reference concentration

Ingestion

COPC	Concentration Noncarcinogen (mg/l)	Concentration Carcinogen (mg/l)	Ingestion Rate (L/day) Adult	Exposure Frequency (day/year) Adult	Exposure Duration (year) Adult	Body Weight (kg) Adult	Average Carc Time (days)	Carc Dose (mg/kg-day) Adult	Slope Factor (mg/kg-day)-1	Carcinogenic Risk Adult	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Adult	Reference Dose (mg/kg-day)	Noncarcinogenic Risk Adult
1,2-Dichloroethene (total)	0.330	NA	2	350	30	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	9.0E-03	9.0E-03	1.0E+00
Trichloroethene	0.210	0.75	2	350	30	70	25550	8.8E-03	1.1E-02	9.7E-05	10950	5.8E-03	6.0E-03	9.6E-01
Benzene	190.000	0.28	2	350	30	70	25550	3.3E-03	2.9E-02	9.5E-05	10950	5.2E+00	0.0E+00	0.0E+00
Tetrachloroethene	0.320	0.145	2	350	30	70	25550	1.7E-03	5.2E-02	8.9E-05	10950	8.8E-03	1.0E-02	8.8E-01
Antimony	0.015	NA	2	350	30	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	4.1E-04	4.0E-04	1.0E+00
Arsenic	0.011	0.0056	2	350	30	70	25550	6.6E-05	1.5E+00	9.9E-05	10950	3.0E-04	3.0E-04	1.0E+00
Iron	11.000	NA	2	350	30	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	3.0E-01	3.0E-01	1.0E+00
TOTAL														

Dermal Contact

COPC	Concentration Noncarcinogen (mg/l)	Concentration Carcinogen (mg/l)	Surface Area (cm2) Adult	Dermal Permeability (cm/hr)	Exposure Time (hours/day) Adult	Exposure Frequency (days/yr) Adult	Exposure Duration (years) Adult	Volumetric Conversion (L/m3)	Body Weight (kg) Adult	Averaging Carc Time (years)	Carc Dose (mg/kg-day) Adult	Derm. Adj. Slope Factor (mg/kg-day)-1	Carcinogenic Risk Adult	Average Noncarc Time (years)	Noncarc Dose (mg/kg-day) Adult	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarc Risk Adult
1,2-Dichloroethene (total)	0.330	NA	23000	1.00E-02	0.25	350	30	0.001	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	2.6E-04	7.2E-03	3.6E-02
Trichloroethene	0.210	0.75	23000	1.60E-02	0.25	350	30	0.001	70	25550	4.1E-04	1.4E-02	5.6E-06	10950	2.6E-04	4.8E-03	5.5E-02
Benzene	190.000	0.28	23000	2.10E-02	0.25	350	30	0.001	70	25550	2.0E-04	3.6E-02	7.2E-06	10950	3.1E-01	0.0E+00	0.0E+00
Tetrachloroethene	0.320	0.145	23000	4.50E-02	0.25	350	30	0.001	70	25550	2.2E-04	6.5E-02	1.4E-05	10950	1.1E-03	8.0E-03	1.4E-01
Antimony	0.015	NA	23000	1.00E-03	0.25	350	30	0.001	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	1.2E-06	8.0E-05	1.5E-02
Arsenic	0.011	0.0056	23000	1.00E-03	0.25	350	30	0.001	70	25550	1.9E-07	7.5E+00	1.4E-06	10950	8.7E-07	6.0E-05	1.4E-02
Iron	11.000	NA	23000	1.00E-03	0.25	350	30	0.001	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	8.7E-04	6.0E-02	1.4E-02
TOTAL																	

Inhalation

COPC	Concentration (mg/l)	Concentration mg/kg/shwr	Exposure Duration years	Exposure Frequency shwr/year	Avg. Time noncarc. days	Avg. Time carc. days	Noncarc. Dose mg/kg/d	Carc. Dose mg/kg/d	Inhalation Reference Conc. mg/kg/d	Inhalation Potency Factor (mg/kg/d)^-1	Noncarc. Risk	Cancer Risk
NA for metals												
1,2-Dichloroethene (total)	0.33	3.6E-06	30	350	10950	25550	3.5E-06	1.5E-06	0.0E+00	0.0E+00	—	0.0E+00
Trichloroethene	0.21	2.1E-06	30	350	10950	25550	2.0E-06	8.5E-07	0.0E+00	6.0E-03	—	5.1E-09
Benzene	190	1.9E-03	30	350	10950	25550	1.8E-03	7.7E-04	1.7E-03	2.9E-02	1.0E+00	2.2E-05
Benzene	0.28	2.7E-06	30	350	10950	25550	2.6E-06	1.1E-06	1.7E-03	2.9E-02	1.5E-03	3.3E-08
Tetrachloroethene	0.32	2.9E-06	30	350	10950	25550	2.8E-06	1.2E-06	0.0E+00	2.0E-03	—	2.4E-09

APPENDIX B

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APPENDIX C
IN-WELL AERATION TECHNICAL INFORMATION

BIOREMEDIATION BY GROUNDWATER CIRCULATION USING THE VACUUM-VAPORIZER-WELL (UVB) TECHNOLOGY: BASICS AND CASE STUDY

W. Buermann and G. Bott-Breuning

INTRODUCTION

Not only in the industrialized countries, but worldwide, the numbe of known groundwater and soil air contaminations by hydrocarbons benzene, toluene, ethylbenzene, and xylenes (BTEX); pesticides; nitrates etc., increases. Efficient, low-cost remediation techniques are needed.

A new method for the in situ remediation of groundwater and soi air is the vacuum-vaporizer-well (UVB) technology (German: Unterdruck Verdampfer-Brunnen [UVB]; invented by B. Bernhardt; patents: IEG mbH D-7410 Reutlingen). The disadvantages of groundwater remediatio applying current pumping methods (groundwater lowering, limited yield insufficient remediation) may be avoided if pumping and recharge tak place in the same well. The UVB technology applies this circulation wel concept.

The basics of hydromechanical theory are outlined in some detai (Buermann 1990, Bürmann 1991). Results of the field measurement conducted in Karlsruhe, Germany, to verify the UVB technology hav been published briefly (Bürmann 1992, Bürmann & Wagner 1992) anc are presented.

A case study on the bioremediation of pesticide (triazines)-contaminated groundwater is presented. Activated carbon is placed within the UVB well as a biofilter. A decrease in triazine concentrations in the ground-water is documented. An increase in the number of bacteria in the aquife was observed and suggests a stimulation of biological processes. Develop-ment of metabolites within the activated carbon filter provides evidence of triazine biotransformation.

Operation of the Vacuum-Vaporizer-Well: UVB Technology. The UVB produces a circulation flow within the surrounding groundwater, directed from the upper to the lower screening, as seen in Figure 1. Water is sucked into the lower screening, transported upwards inside the UVB by the water pump (air lift pump), and cleaned by fresh air in the stripping zone under below-atmospheric pressure before flowing out of the UVB through the upper screening. This all takes place without the water leaving the aquifer. If necessary, the groundwater is cleaned on site and directed back to the well. Soil air from the unsaturated zone of the aquifer may be sucked into the UVB through the upper screening and thus also may be cleaned. The contaminants in the stripping air are adsorbed by activated carbon. To avoid precipitation, the stripping air loop is closed. Thus contaminants that are not adsorbed can be kept from escaping into the atmosphere (Herrling et al. 1992).

In resting groundwater, circulation creates a permanent flow and consequently cleans the soil within the zone of the well, as all the circulating water flows through the well. Natural groundwater flow, which exists in most cases, deforms the circulation flow so that a portion of the water flowing toward the intake zone of the well may pass the well several times, due to the continual circulation flow, whereas the remainder of the water flows through the well only once. Therefore, the cleaning equipment of the UVB must be dimensioned so that one flow through the well is sufficient to ensure decontamination of the water.

Groundwater Flow around the UVB. The circulation flow depends on the natural groundwater flow, the water flowrate through the well, the water-saturated thickness of the aquifer (corresponding to the length of the well), the lengths of the lower and upper screenings, the outer radius of the well, and the horizontal and vertical conductivities of the aquifer (Buermann 1990).

The circulation flow may be influenced only by the design of the well itself, and in particular by the water flowrate. If existing wells must be used, water flowrate is the only means of control of the circulation flow.

In resting groundwater, the investigations give a theoretically unlimited zone of effect of the well. For a realistic judgment of the zone of effect, a radius around the well is chosen that contains a specific percentage of the total quantity of water flowing inside the well. The influence of the screening length is small. For realistic values of the anisotropy of the aquifer, the radius of effect is approximately 1.5 to 2 times the water-saturated aquifer thickness.

The circulation flow in moving groundwater shows two separating streamlines, at the bottom and at the top of the aquifer, similar to the

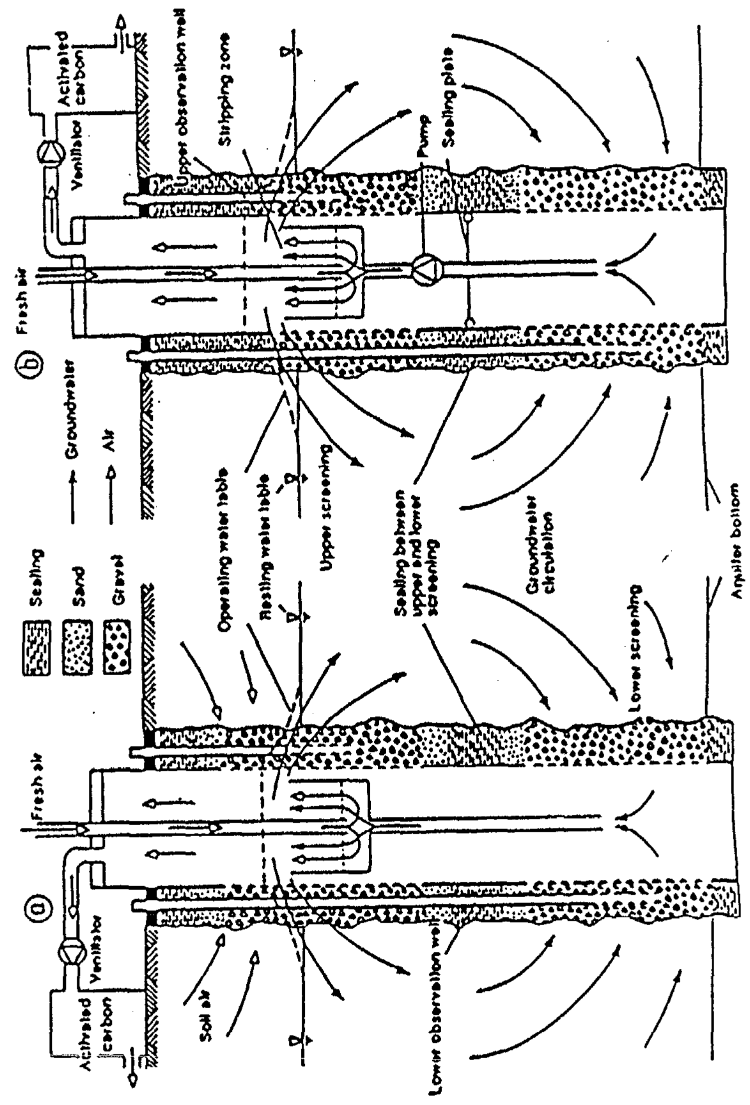


FIGURE 1.

perfect well (Figure 2). In a well with upward flow, the lower separating streamline corresponds to the withdrawal well and the upper one to the infiltration well. Between these two separating streamlines at the lower and upper boundaries of the aquifer lies the separating stream surface of the flow around the well in the natural groundwater. This surface consists of spatial streamlines and shows a different contour in each horizontal section.

The dimension of the separating stream surface is characterized by the distance of the stagnation point S from the well. Figure 3 shows the water flowrate over the stagnation point distance of the upper separating streamline. The lower stagnation point distance gives the same curves for equal lengths in the lower and upper screening, and the curves remain essentially the same even for very different screening lengths. The smaller the ratio of vertical and horizontal conductivity, the greater the stagnation point distance and the influence zone of the well.

The water flowrate through the well rises more than proportional with the stagnation point distance. Therefore, instead of one single well of a large water flowrate, several wells of small rates may be useful.

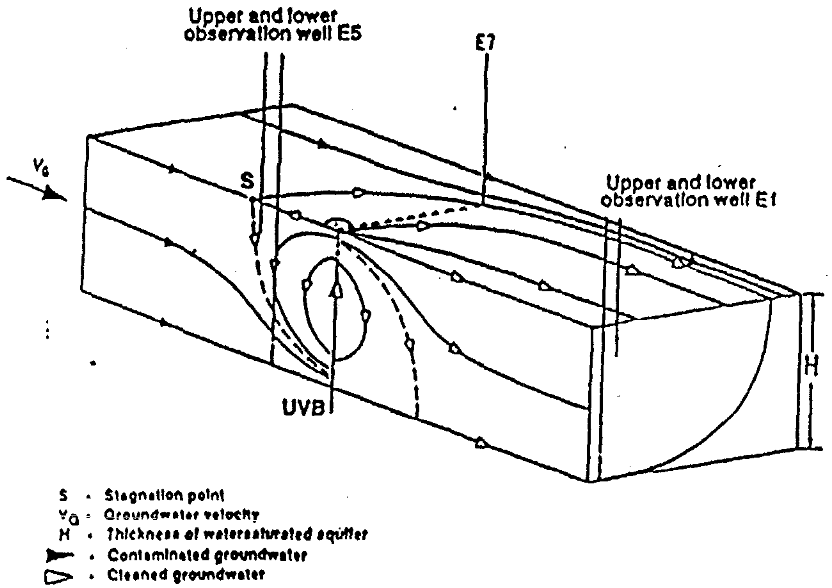


FIGURE 2. Typical flow pattern of the vacuum-vaporizer-well (UVB) in natural groundwater flow.

CASE STUDY OF A BIOLOGICAL REMEDIATION

The UVB technology offers not only an innovative method of physically remediating contaminated sites, but also makes in situ biological remediation of groundwater possible. As a case study, a combined physical and biological remediation of groundwater containing pesticides (triazines) is presented (Figure 4).

The darcy velocity of the natural groundwater flow of 0.17 m/d, the water-saturated thickness of the aquifer of 6.6 m, the anisotropy k_V/k_H of 0.1, the screening length of 2 m, and the water flowrate inside the UVB of 4 m^3/h give the stagnation point distance of about 13 m in Figure 3.

Principle of Bioremediation. The principle behind every bioremediation is optimizing the environmental conditions for the naturally existing, already adapted microorganisms. Oxygen often is a limiting factor for aerobic degradation. The part of the aquifer where the UVB creates a continuous circular flow is regarded as an in situ bioreactor and is constantly supplied with oxygen-enriched water. Additional nutrients needed by the bacteria can easily be injected into the circulation flow that

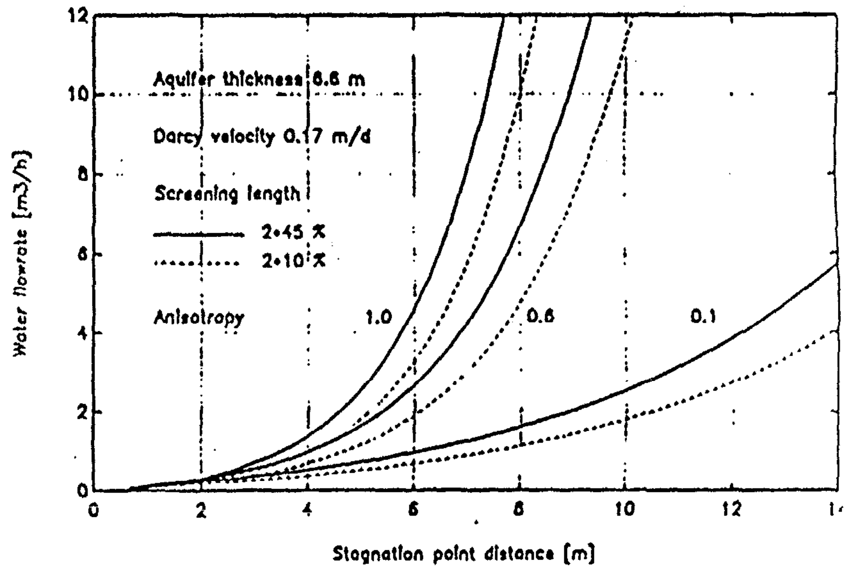


FIGURE 3. Water flowrate over stagnation point distance of the vacuum-vaporizer-well (UVB) in natural groundwater flow.

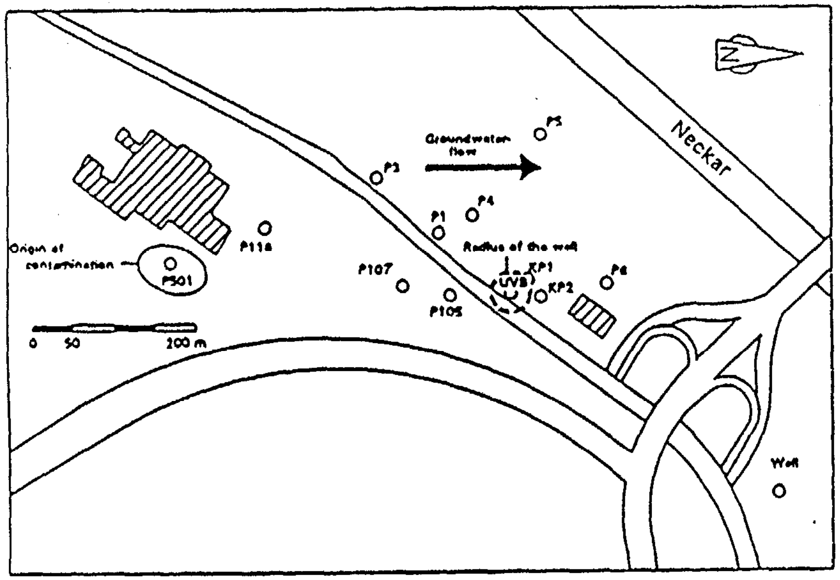


FIGURE 4. Schematic map of the contaminated site.

the UVB creates within the aquifer. These nutrients enable optimal conditions to be created for the microorganisms bound on grain surfaces.

In the case study presented in this paper, activated carbon was used as a biofilter within the UVB. The two variations shown in Figure 5 were tested. In both cases the contaminants and the triazine-degrading bacteria are adsorbed onto the activated carbon by constant circulation of contaminated groundwater in the well. This accumulation is a special advantage in cases with low contaminant concentrations or few bacteria in the groundwater. Adding specific nutrient supply for the bacteria to the biofilter is possible.

Results of the Triazine Remediation. In Figure 6, the concentration curves of the total triazines (atrazine, propazine, simazine, and triazine metabolites) entering and leaving the biofilter are depicted. The amount of triazines in the groundwater entering the activated carbon is higher than that leaving the biofilter. This decontamination is the result of adsorption of triazines onto and biological degradation processes within the activated carbon.

During biodegradation of triazines, various intermediates are formed (Cook 1987). These were detected in the aquifer before remediation with the UVB technique began. Figure 7 shows the concentration curve of one

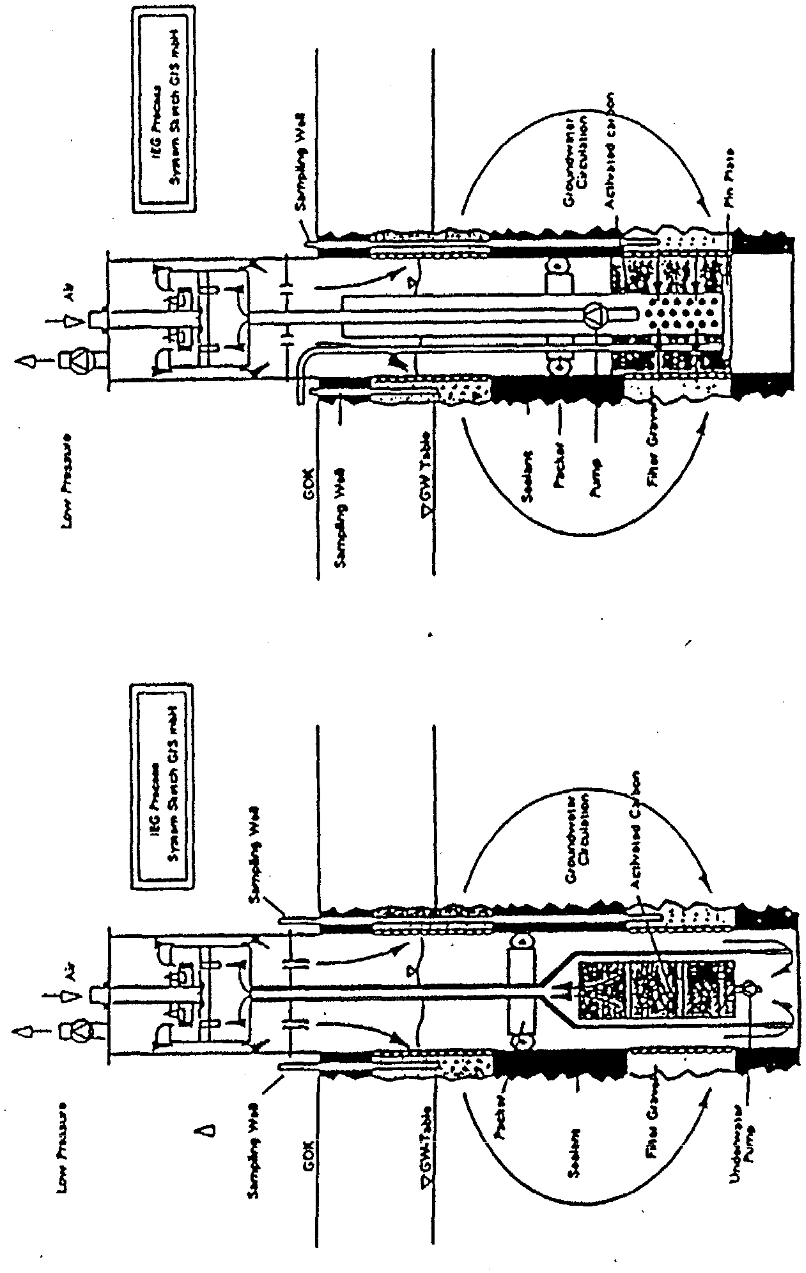


FIGURE 5. Version 1 (left) and version 2 (right) with the biofilter implemented (schematic).

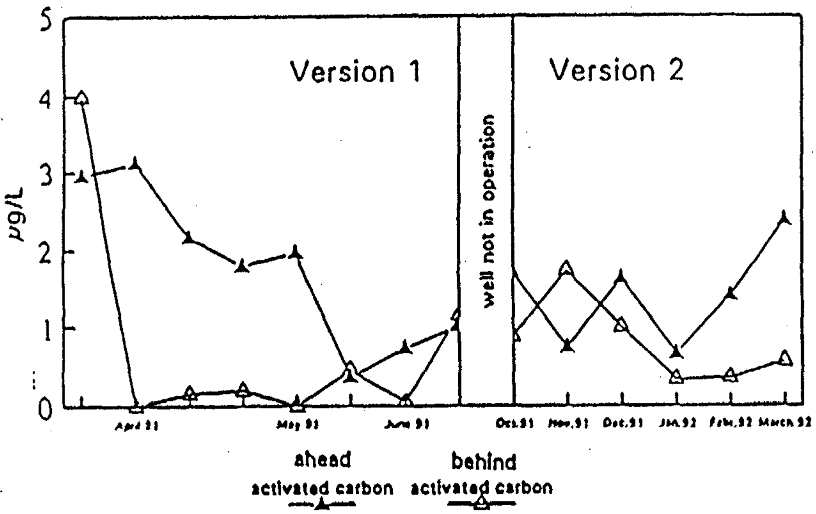


FIGURE 6. Concentration curve of triazines in groundwater entering and leaving the biofilter.

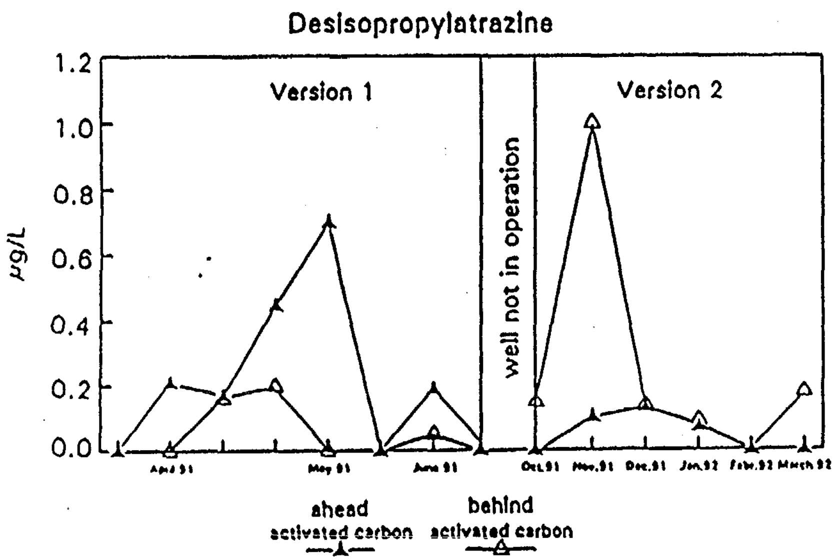


FIGURE 7. Metabolite concentration (desisopropylatrazine) in groundwater entering and leaving the biofilter.

of these metabolites, desisopropylatrazine, in groundwater before anc after treatment by the activated carbon. The higher metabolite concen tration behind the activated carbon indicates that further biological trans formation of triazines occurs in the biofilter. This intermediate is furthe: reduced by biodegradation. Figure 8 depicts the decrease of triazin concentrations in groundwater of the monitoring well KP1.

In addition to using intermediates as an indication of biodegradation it is possible to count the number of bacteria in a sample. This wa: carried out by the colony-forming-units (CFU) method, in which bacteri: are cultivated under aerobic conditions on a defined standard nutrien supplier. Table 1 shows the development of the number of bacteria ir samples taken from various wells. Within 3 months the number of bac teria in monitoring well KP1 increased by a factor of 1,000, and the triazin concentration decreased accordingly. A biofilm developed on the acti vated carbon from April to June 1991. It was analyzed qualitatively anc quantitatively. The number of CFUs was 7.7×10^4/g activated carbon which is an enrichment compared to the number of bacteria (470 CFU/ml groundwater) ahead of the activated carbon biofilter.

CONCLUSIONS

The combined physical and biological remediation of triazine contaminated groundwater using the UVB technology shows good succes:

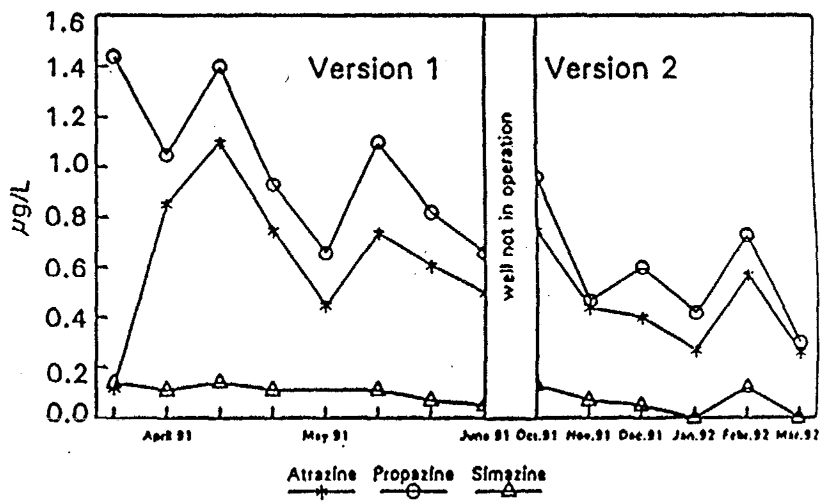


FIGURE 8. Triazine concentrations in the groundwater at monitoring well KP1.

TABLE 1. Development of bacteria (CFU/mL groundwater).

Date	Entering Activated Carbon	Leaving Activated Carbon	Monitoring Well KP1	Monitoring Well KP2
October 1991	4.7*10^2		2.5*10^3	
January 1992	1.8*10^3	3.1*10^4	3.5*10^6	7.5*10^3

in decreasing the triazine concentrations during remediation to date. The simultaneous increase in the number of bacteria in the aquifer suggests stimulation of biological processes. The development of metabolites and the increasing remediation rate within the activated carbon are evidence of biological triazine transformation. Further investigations include determination of degradation rate, looking for proof of specific triazine-degrading bacteria both in the aquifer and in the biofilter, and optimizing the biofilter.

ACKNOWLEDGMENTS

The authors gratefully acknowledge IEG mbH, D-7410 Reutlingen, for funding the investigations, and in particular, B. Bernhardt, IEG mbH, and many others for their work and their numerous helpful discussions and contributions concerning the UVB technology.

REFERENCES

Buermann, W. 1990. "Investigation of the circulation flow around a combined withdrawal and infiltration well for groundwater remediation demonstrated for the Underpressure-Vaporizer-Well (UVB)." In F. Arendt et al. (Eds.), *Contaminated Soil '90*, pp. 1045-1052. Third International KfK/TNO Conference on Contaminated Soil, Karlsruhe, December 10-14, 1990. Kluwer Academic Publ., Dordrecht, Boston, London.

Bürmann, W. 1991. "Zur Zirkulationsströmung am Unterdruck-Verdampfer-Brunnen (UVB)." In *Umweltplanung, Arbeits- und Umweltschutz 121*, pp. 64-80. Hessische Landesanstalt für Umweltschutz, Wiesbaden, Germany.

Bürmann, W. 1992. *Zusammenstellung der Meßergebnisse der Untersuchungen am Unterdruck-Verdampfer-Brunnen (UVB) im Karlsruher Versuchsfeld.* Bericht Nr. 698, Institut für Hydromechanik, Universität Karlsruhe, Karlsruhe,

Bürmann, W., and H. Wagner. 1992. "Remediation by groundwater and soil/air circulation in situ using the vacuum-vaporizer-well (UVB) technology." *Budapest '92 Proceedings*, International Symposium on Environmental Contamination in Central and Eastern Europe, October 12-16, Budapest, in press.

Cook, A. 1987. "Biodegradation of s-triazine xenobiotics." *FEMS Microb. Rev. 46*: 93-116.

Herrling, B., W. Buermann, and J. Stamm. 1992. "In-situ remediation of volatile contaminants in groundwater by a new systen of vacuum-vaporizer-wells (UVB)." In K. U. Weyer (Ed.), *Subsurface Contamination by Immiscible Fluids*, pp. 351-359. A. A. Balkema Publ., Rotterdam, Brookfield.

EG&G ENVIRONMENTAL

A TECHNOLOGY AND SYSTEMS INTEGRATION COMPANY

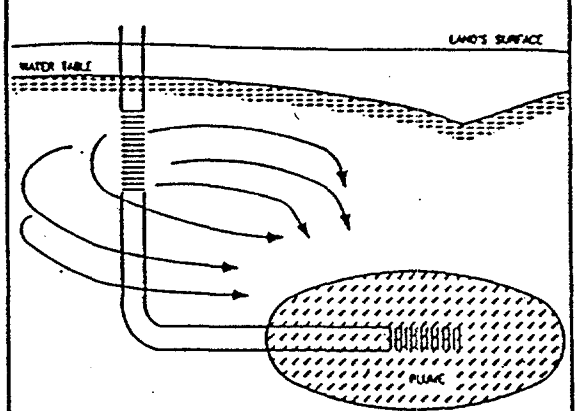
NoVOCs SYSTEM: IN-WELL STRIPPING OF VOCs FROM GROUNDWATER

THE CONCEPT

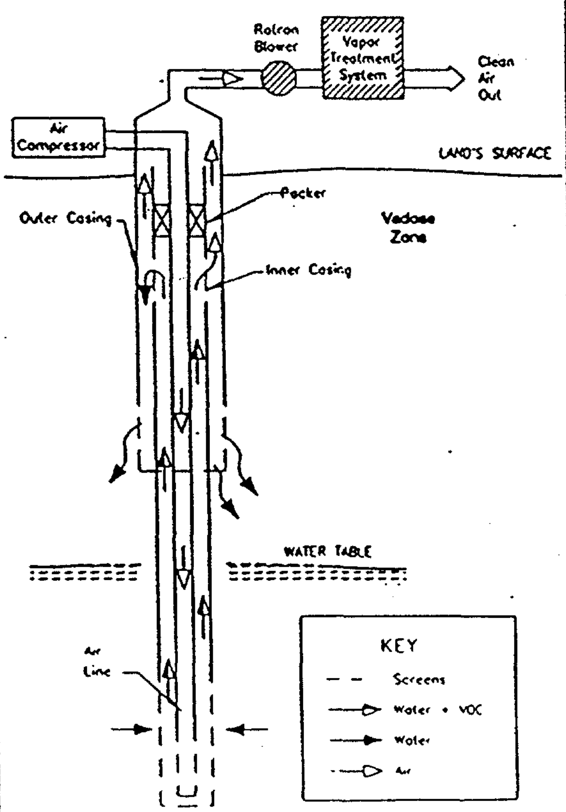
EG&G Environmental, Inc., through its NoVOCs division, offers a cost-effective new technology for removing volatile organic compounds (VOCs) from contaminated groundwater (US Patent No. 5,180,503). Traditional remedies for removing petroleum hydrocarbons and chlorinated solvents in the groundwater have relied upon extraction wells to bring contaminated water to the surface, followed by one of several treatment alternatives to remove contaminants from the aqueous phase. These options include: air stripping, activated carbon, and UV-peroxide oxidation.

In-well stripping, however, simplifies the process and results in significant savings by eliminating separate above-ground aqueous phase treatment.

HORIZONTAL NoVOCs WELL



OPERATION OF A NoVOCs WELL



In-well stripping operates on the same principle as the aerator in an aquarium. A compressor is used to deliver air or an inert gas such as nitrogen to the water column within an extraction well. The resulting bubbles in the water constitute an air lift pump. Because the water with bubbles has a lower density than water outside the well, a pressure gradient is established which causes water outside the well to flow into it through the lower screened section. The bubble-water mixture rises in the well. At the same time, VOCs in the water volatilize into the bubbles. The bubble-water mixture is allowed to rise to a point where optimum volatilization has occurred. The casing is screened at that point and sealed with a deflector plate.

When the mixture encounters the deflector plate, the bubbles break and combine. Water then flows through the upper screen and is allowed to reinfiltrate into the vadose (above water table) zone. A larger casing placed over the top of the well is maintained under vacuum; it allows coalesced bubbles to be drawn off for treatment above ground. Reinfiltrating water creates a torroidal circulation pattern around the well so that waters can be treated through multiple cycles to achieve the desired level of removal

EG&G ENVIRONMENTAL

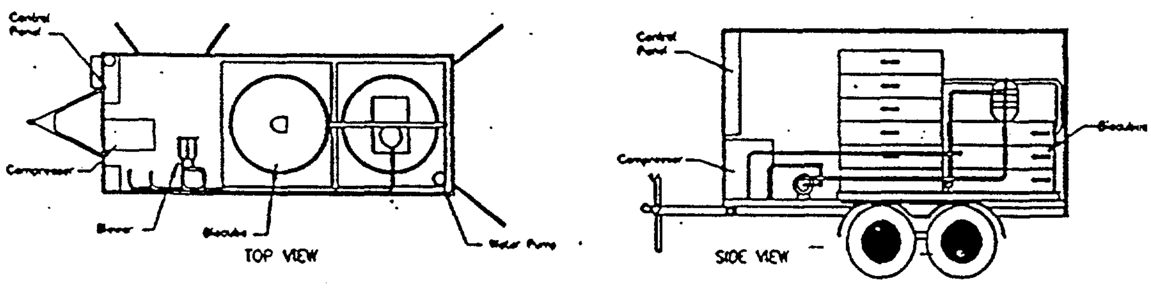
ADVANTAGES

In-well stripping offers a number of advantages over traditional pump and treat technologies:

- *Reduces Capital Costs*
- *Reduces Operating Costs Associated With Pumping Vapor, Not Water, to the Surface*
- *Accelerates Restoration Due to Disruption of Free Phase Product in the Capillary Fringe*
- *Enhances Bioremediation of Hydrocarbons as a Result of Aeration/Recirculation of Treated Water*
- *Eliminates Need for Reinjection Wells, Discharge Lines and Discharge Fees*
- *Facilitates Coupling with Soil Vapor Extraction Systems*
- *Minimizes Installation Time/Cost Through Use of Integrated System Mobile Unit*

In-well technology is available with a full set of related services, including consultation, design, installation, operation and monitoring. Designs include new installation and retrofits for existing extraction wells.

MOBILE UNIT FOR HYDROCARBON RECOVERY WITH NoVOCs SYSTEM



ABOUT EG&G ENVIRONMENTAL, INC.

EG&G Environmental is a wholly-owned subsidiary of EG&G, Inc., a Fortune 200 company. EG&G Environmental was formed in January 1994 to harness the recognized strengths of the parent corporation, build on them, and apply them in environmental problem solving. EG&G Environmental offers services and products in four strategic areas: *1) Consulting Services; 2) Technology Products; 3) Systems Integration; and 4) Integrated Environmental Management.*

For further information on in-well stripping technology or other products and services from EG&G Environmental, contact the Pittsburgh headquarters office or the Richland, Washington office.

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PITTSBURGH, PA 15220
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W RICHLAND, WA 99352
(509) 967-2347
FAX (509) 967-5709

APPENDIX D
VENDOR QUOTES

Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812

QUOTATION

SYSTEMS

Baker Environmental
Airport Office Park, Bldg. 3
Coraopolis, PA
15108
Attn: Mark DeJohn
Phone: 412-269-6007
FAX: 412-269-2002

Quote # 960783-00
Date: 04/26/96
Terms: Net 30 days
Freight: prepaid and added
FOB Addison
Quotation is valid for 60 days

Quote Specifications:

REF: F.S. Project # 303; Camp LeJune Site 86.

SYSTEM ELECTRICAL:
1/60/230 3 wire plus ground service,
brought to NEMA 3R exterior panel
Motors will be totally enclosed fan cooled

PUMPING SYSTEM DESIGN CRITERIA:

Qty	Diameter	Well Depth	GTS	Flow/Well
3	6"	60'	5'	15 GPM

TOTAL FLOW: 45 GPM @ 55 F LNAPL: NOT PRESENT

WATER TREATMENT DESIGN CRITERIA:

Contaminant	Dissolved Product: Concentration (ppb)	Discharge Limit (ppb)	After ESI Air Stripper (ppb)
TCE	400	2.0	< 1
PCE	77	0.7	< 1
Benzene	8	1.0	< 1
1,2 DCE	140	70.0	< 1

We offer the following:

1 REMEDIATION SYSTEM 36,501.0
INCLUDING:
* INSULATED ENCLOSURE: 8'W x 12'L x 8.5'H
with LIGHT, HEATER and THERMOSTAT
Equipment is mounted on a steel platform with coated plywood deck. The enclosure consists of structural steel members and pre-assembled panels with aluminum skin. The enclosure incorporates one locking hinged door.
The side panels will be easily removable for additional access to the equipment for easier maintenance.
The breaker panel and control panel will be mounted on a vertical steel bracket attached to platform end.
The bracket, panels and all conduits will allow for the removal of the enclosure side panels by one person.
A single power connection will be provided by others.

* CASCADE LP 5004 AIR STRIPPER
4 trays with 5 HP blower
with: Effluent Transfer Pump - 1-1/2 HP
with: High Sump Level Switch LEVEL SWITCHES
with: High/Low Air Pressure Switches
with: Sample Ports
STANDARD AIR STRIPPER INCLUDES:

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1-800-OIL-LEAK
Fax 708-543-2014

Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812

Epoxy Coated Steel Trays
* 6" tray clean out ports (8 per tray)
* removable nylon aeration tubes (7 per tray)
* quick-release tray latches (10 per tray)

Lid with Demister and 8" Exhaust Port

Aluminum Blower
* air pressure gauge
* inlet gaurd with damper

Integral Effluent Sump Base
* 100 gallon working capacity
* 8" clean out/inspection hatch
* removable sight glass with shut off valve

* ELECTRIC SUBMERSIBLE PUMP SYSTEM FOR 3 WELLS:
  * Grundfos Model 16E4 pump (15 gpm @ 85' TDH)
  * Panel-mounted controls
  * cable anchor with well mount
  * downwell hose, wires and jacketed motor leads
  * all additional straps, clamps and fittings for pump installation

* ELECTRICAL DISTRIBUTION & CONTROLS

BREAKER PANEL:
* NEMA 3R enclosure
* Main disconnect
* breaker panel with individual branch breakers for all major components

CONTROL PANEL:
* NEMA 3R enclosure
* control panel with magnetic starters, door-mounted hand switches, intrinsically-safe barriers and hard-wired relay logic.
* individual conduit runs with poured seal-offs for motors, interior light, safety circuit(s) and heater circuit.
* definite-purpose contactor for electric pump shut-off

INTERLOCKS:
* Groundwater pump(s) shut off upon:
  * Air stripper blower failure or over-pressure condition
  * Air stripper sump high liquid level
* Interlocks are latching, pushbutton reset.

>>>>> OPTIONS NOT INCLUDED IN NET TOTAL <<<<<

* SUSPENDED SOLIDS BAG FILTER.................... $ 1,175.00
  * 5.0 sq. ft. surface area
  * 180 gpm flow capacity
  * 75 psi coated pressure tank
  * 25 micron filtration
  * 3 replacement bags included
  * quick opening clamp cover
  * differential gauge
  * by-pass line

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1-800-OIL-LEAK
Fax 708-543-2014

Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812

SYSTEMS

NET TOTAL:	36,501.00

Yours truly,
EJECTOR SYSTEMS, INC.

David Ogilvie
Sales Engineer

708-543-2214
1-800-OIL-LEAK
Fax 708-543-2014

FAX

EG&G Environmental

Date May 7, 1996

Number of pages including cover sheet 8

To:

Mark DeJohn

Baker Environmental

Phone

Fax Phone 269-2002

CC: T. Hawk

From:

Wayne J. DiBartola

EG&G Environmental, Inc.

Foster Plaza 6, Suite 400

681 Andersen Drive

Pittsburgh, PA 15220

Phone (412) 920-5401

Fax Phone (412) 920-5402

REMARKS:

☐ Urgent ☐ For your review ☐ Reply ASAP ☐ Please comment

EG&G

EG&G ENVIRONMENTAL
FOSTER PLAZA 6, SUITE 400
681 ANDERSEN DRIVE
PITTSBURGH, PA 15220
PHONE: (412) 920-5401

May 7, 1996

Mr. Mark DeJohn
Baker Environmental, Inc.
Airport Office Park
Coraopolis, PA 15108

Re: Camp LeJeune Site #86
EG&GE Ref. No. 7002-105

Dear Mark,

Please find attached our budgetary NoVOCs™ proposal for the referenced site.

We trust that the enclosed technical data and prices are sufficient for your purposes at this time.

Should you require additional information, please advise.

We look forward to the prospect of working with you on this project.

Very truly yours,

Wayne

Wayne J. DiBartola
Vice President

cc: T. Hawk

MARINE CORPS BASE CAMP LEJEUNE, SITE 86
PRELIMINARY NoVOCs™ DESIGN AND PRICE ESTIMATE

EG&G Environmental, Inc., (EG&GE) has prepared a preliminary design and price estimate for a NoVOCs™ system for groundwater contamination at Marine Corps Base (MCB) Camp Lejeune, Site 86, in North Carolina. The system would consist of twelve NoVOCs™ wells and associated air handling and off-gas treatment equipment. The system would be operated to remediate a groundwater plume containing trichloroethylene (TCE), tetrachloroethylene (PCE), 1,2-dichloroethylene (12DCE), and benzene.

The following summarizes the design basis and features for the proposed system. This design is based on information provided to EG&GE by Baker Environmental, Inc., (Baker). Section 1.0 summarizes this design information. The specifications and price of the system are presented in Sections 2.0 and 3.0, respectively.

1.0 DESIGN INFORMATION

Information needed to design a NoVOCs™ groundwater treatment system includes characteristics of the contaminant plume, cleanup goals, and geohydrologic characteristics. Design information relevant to this site is described below.

1.1 Plume Characteristics

Plume characteristics were provided to EG&GE by Baker. The plume is reportedly 560 ft long by 520 ft wide by 35 ft deep. The zone of contamination exists below the top of the aquifer. From cross-sections provided to EG&GE, the distance from the water table to the top of the zone of contamination appears to range from 14 ft to 27 ft.

1.2 Contaminant Concentrations and Cleanup Goals

The groundwater monitoring data provided indicate the following maximum contaminant concentrations: 1ST ROUND DATA PROVIDED

TCE – 190 μg/L 400 (2ND ROUND)
PCE – 77 μg/L
12DCE – 73 μg/L 140 (2ND ROUND)
Benzene – 8 μg/L

The following are the groundwater cleanup goals for this site:

TCE – 5 μg/L
PCE – 0.7 μg/L
12DCE – 70 μg/L
Benzene – 1 μg/L

1.3 Geohydrologic Characteristics

Geohydrologic characteristics needed to design the NoVOCs™ system are stratigraphy, depth to groundwater, horizontal hydraulic conductivity, anisotropy ratio (ratio of horizontal to vertical hydraulic conductivity), hydraulic gradient, and porosity. Geohydrologic data used for the design are summarized in Table 1.

Table 1. Summary of Geohydrologic Data Used for Design

Parameter	Value	Source
Stratigraphy	Vadose zone -- overlapping layers of silty clay, silty fine sand, sandy clay and clay. Surficial aquifer -- fine sand and fossiliferous limestone beds.	Cross-sections provided by Baker.
Depth to groundwater	5 to 6 ft.	Provided by Baker.
Horizontal hydraulic conductivity	3.4 ft/day (1.2×10^{-3} cm/sec)	Provided by Baker.
Anisotropy ratio	10	Assumed based on stratigraphy.
Hydraulic gradient	0.004 ft/ft	Provided by Baker.
Porosity	0.2	Assumed based on stratigraphy.

2.0 System Design

The NoVOCs™ system for this site would consist of twelve wells, installed to an average depth of 60 ft bgs. The wells would be located throughout the entire plume in four rows of three wells each. The wells in each row would be spaced approximately 170 ft apart and the rows would be spaced approximately 140 ft apart. Exact well locations would depend on site-specific access considerations.

The wells would have a design pumping rate of 5 gpm and a design air-water ratio (AWR) of 30. This pumping rate and aquifer conditions would result in treatment zone dimensions of approximately 205 ft by 175 ft for each well. An AWR of 30 would result in concentration reductions of 84% for TCE, 90% for PCE, 85% for 12DCE, and 77% for benzene with each treatment cycle. These removal efficiencies would result in the maximum reported contaminant concentrations being reduced to cleanup goals with two or less treatment cycles. The air injection rate at each well would be 20 cfm.

Figure 1 shows a general schematic of the NoVOCs™ well design for this site. The wells would be constructed of 6-in. PVC. An eductor design would be used so that treated water could be recharged below the water table at the top of the zone of contamination in the surficial aquifer unit. Each well would be constructed with two monitoring points. The lower monitoring point would be screened over the same interval as the NoVOCs™ inlet screen to sample water flowing into the well. The upper monitoring point would be screened over the same interval as the recharge screen to sample the treated water and to monitor head in the recharge zone.

Required air handling and related equipment is summarized in Table 2. All equipment would be located in a trailer placed at a central location. Wells would be connected to the blowers by air lines buried underground. Off-gas would be treated using granular activated carbon (GAC).

Table 2. Equipment for Air Handling System

Air Injection Equipment
7.5-HP regenerative blower
Inlet filter
Bleed-off muffler
Pressure relief valve
Venturi flow meter with gauge
Pressure gauge (blower discharge pressure)
Pressure gauge (blower inlet vacuum/filter restriction)
Valves and plumbing
Vacuum Equipment
7.5-HP regenerative blower
Moisture separator with high level shut down
Vacuum relief valve
Venturi flow meter with gauge
Pressure gauge (blower discharge pressure)
Pressure gauge (blower inlet vacuum)
Valves and plumbing
Off-Gas Treatment Equipment
Two 585-lb GAC units
Mechanical/Electrical Equipment
Equipment trailer with lights and ventilation blower
Electrical control panel
Control panel security cover
Auto-dialer alarm
Conduit and wiring

3.0 PRICE

The estimated price for the NoVOCs™ system described above is $250,000. This estimate is based on the best available design information and includes:

- well drilling, installation, and development;
- mechanical, electrical, and off-gas treatment equipment;
- trenching, installation of air lines, backfilling, and asphalt repair; and

- labor to provide design specifications and drawings, oversee well installation and system startup, and provide technical support as needed during operation.

The estimate includes the cost for containerizing drill cuttings and development water, but does not include disposal costs for these materials. Also, we assumed that 220 volt, 3 phase power and telephone service would be available at the site for the air handling system. The maximum power required by this system would be approximately 11 kw.

The estimated operating and maintenance (O&M) costs for the NoVOCs™ system are summarized in Table 3. Utility costs consist of electrical costs at $0.10/kwh and telephone service. Maintenance costs include routine repairs and preventative maintenance. Labor costs include monthly inspections. Off-gas treatment costs are for regeneration of spent GAC. The GAC usage rates are based on maximum concentrations of contaminants in groundwater. The O&M costs do not include sampling and analysis to monitor cleanup progress.

Table 3. Summary of O&M Costs

Cost Element	Estimated Annual Cost
Utilities	$8,400
Maintenance	$1,000
Labor	$9,000
Off-gas Treatment	$3,200
Total	$21,600

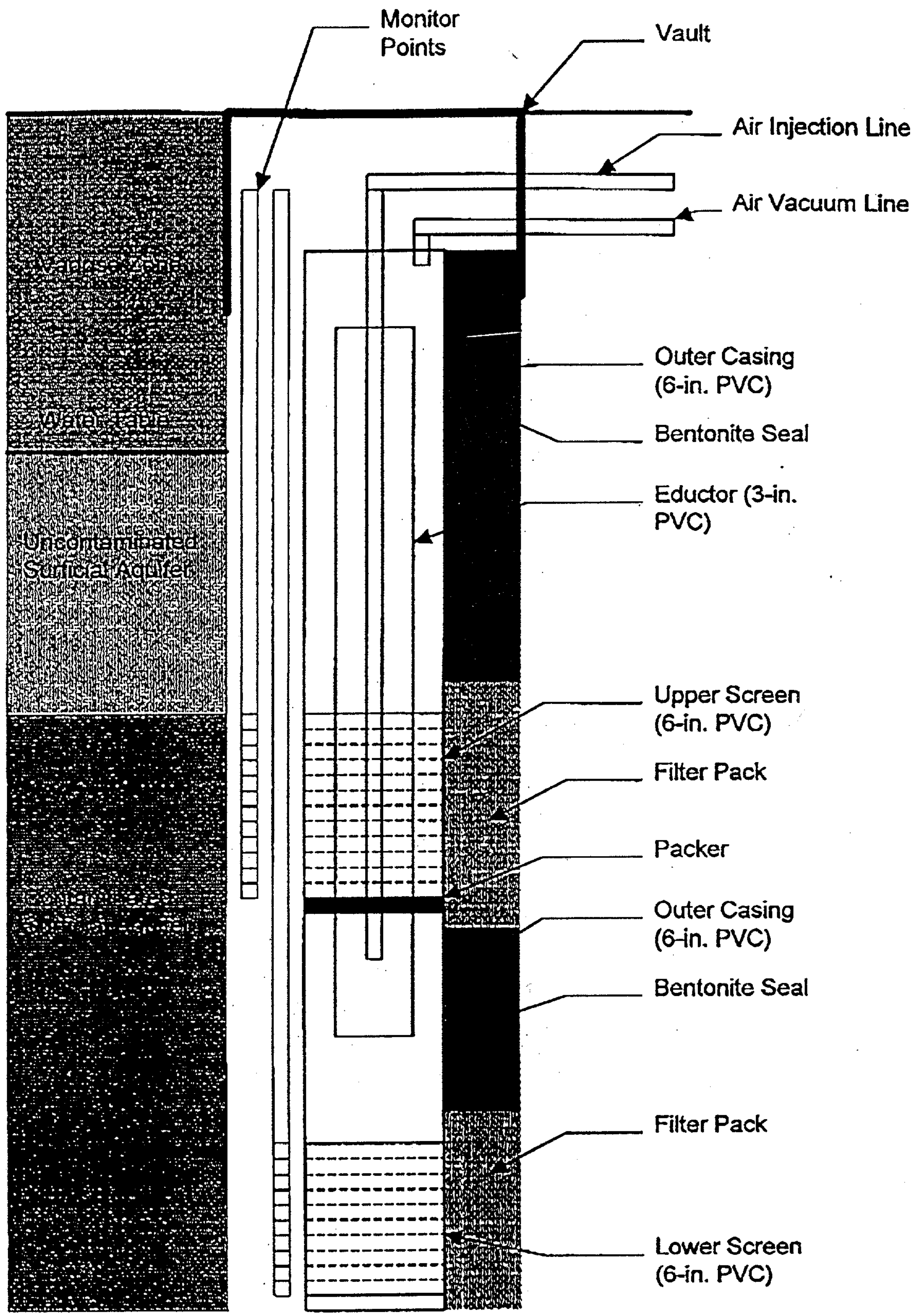
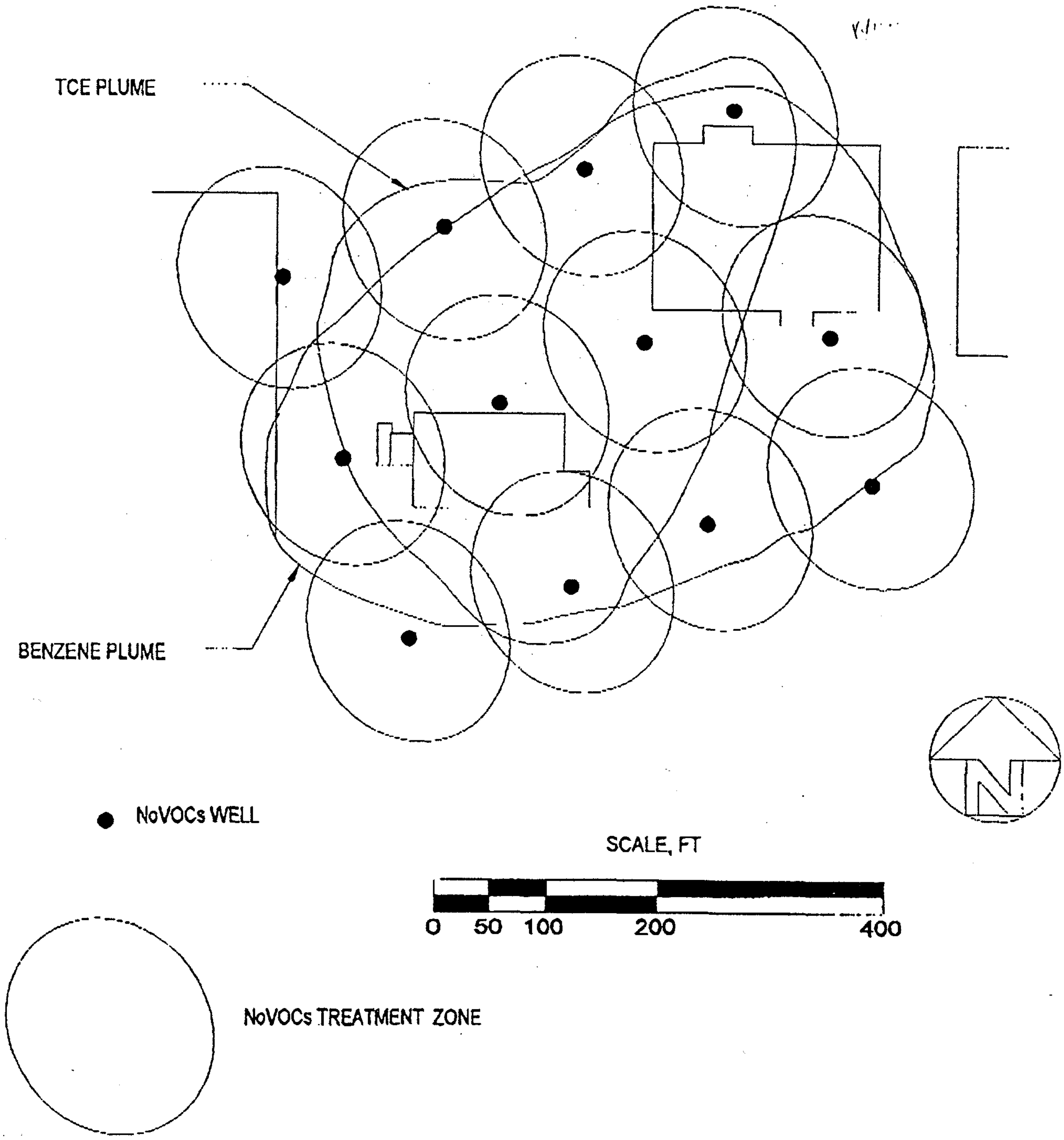


Figure 1. General Schematic of Well Design (Not to Scale)

MCB CAMP LEJEUNE, SITE 86
PRELIMINARY NoVOCs WELL LOCATIONS



1" = 147.857'
178%

BAKER ENVIRONMENTAL, INC.

PHONE CALL REPORT

PROJECT/LOCATION: MCB CLEJ, SITE 86

S.O. No.: CTO-303

DATE: MAY 8, 1996

CONTRACT NO : —

To: WAYNE DIBARTOLA

Repres.: EG&G ENVIRONMENTAL

Phone No.: (412) 920-5401

From: MARK DEJOHN

Repres.: BAKER

Phone No.: (412) 269-6007

SUBJECT: FOLLOWUP QUESTIONS TO EG&G QUOTE FOR IN-WELL AERATION AT SITE 86

Q: WHY THE OVAL SHAPE TO THE TREATMENT ZONE?

A: THE SHAPE WAS BASED ON THE INPUT INFO. PROVIDED BY BAKER

Q: EG&G DIDN'T USE MAX. CONCENTRATIONS FOR TCE & DCE. WHAT AFFECTS WILL THIS HAVE ON THE PROPOSED SYSTEM.

A: THIS WILL ONLY AFFECT THE TREATMENT TIME

Q: WHAT IS THE PROPOSED CLEANUP TIME OF MAX. CONC. PROVIDED IN EG&G QUOTE?

A: 2 YEARS [AUTHOR'S NOTE: EG&G QUOTE SAYS, "TWO OR LESS TREATMENT CYCLES." PRESUME ONE CYCLE EQUALS ONE YEAR].

Q: WELLS ARE SHOWN TO BE FLUSH MOUNT. ARE THE CAPABLE TO WITHSTAND HEAVY TRAFFIC (WEIGHT & FREQUENCY)?

A: NO, ADD ~$1,000 /WELL FOR REINFORCEMENT

PREPARED BY

TITLE

BAKER ENVIRONMENTAL, INC.

PHONE CALL REPORT

.OJECT/LOCATION: CONTINUED

S.O. No.:

DATE:

CONTRACT NO :

To:

Repres.:

Phone No.:

From:

Repres.:

Phone No.:

SUBJECT:

Q: THE CURRENT DESIGN TREATS THE "ENTIRE" PLUME. COULD WE EASILY ADJUST COSTS IF WE CHANGED THE DESIGN TO A CONTAINMENT LINE, WHERE THE PLUME FLOWS TO THE WELLS?

A: THE DESIGN APPROACH WOULD BE DIFFERENT, HOWEVER FOR THIS FS STAGE WE CAN ASSUME SIMILAR COSTS. THE CAPITAL COSTS WOULD BE LESS (FEWER WELLS), BUT O&M COSTS WOULD INCREASE (LONGER TREATMENT TIME).

CC: MKDeJohn; REBonelli; KMChavara; Program File
62470-303

PREPARED BY M. DEJOHN TITLE GEOLOGIST